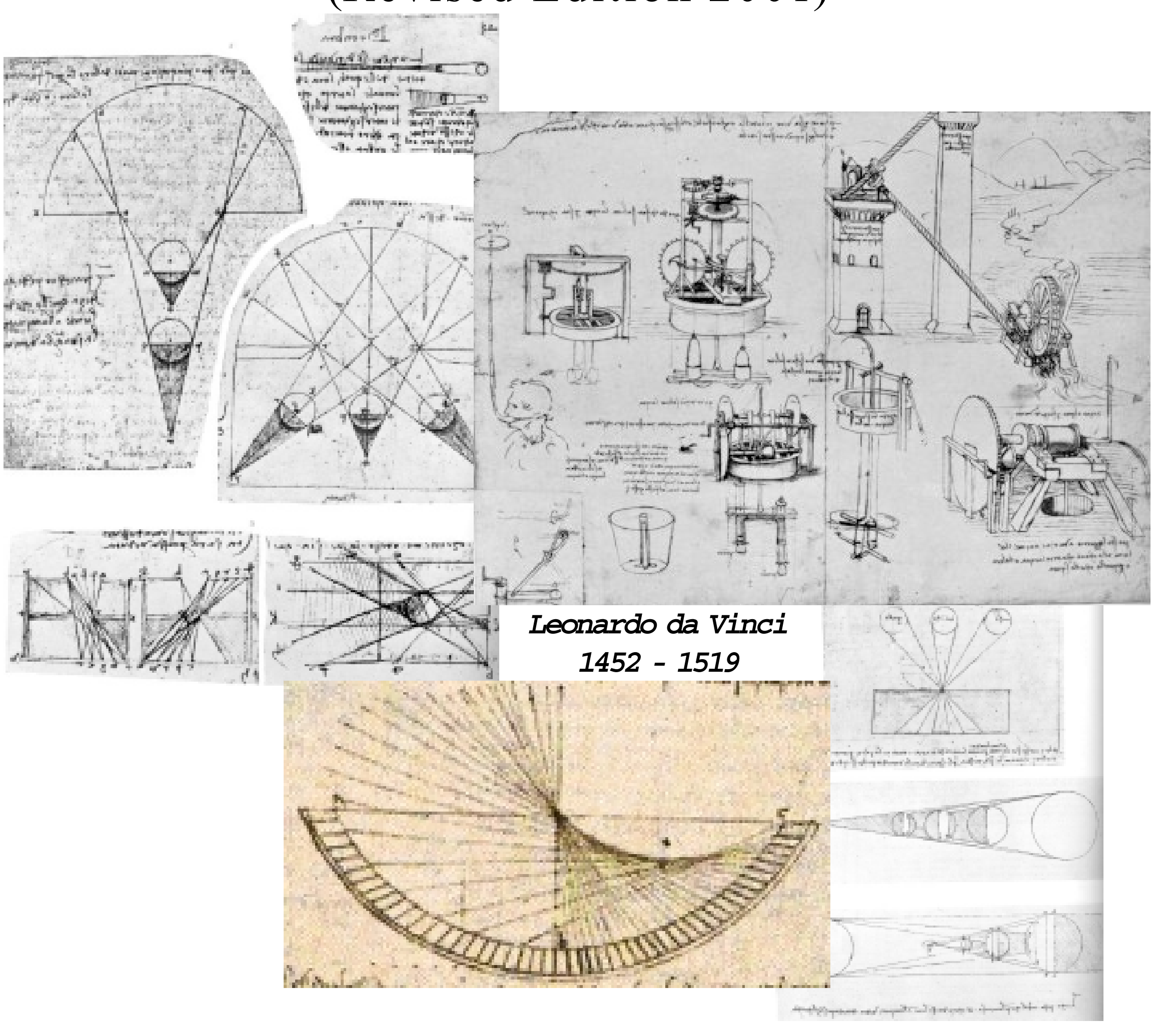
Student Study Guide

PHYSICS 534

(Revised Edition 2001)



Leonardo da Vinci
1452 - 1519

Student Study Guide
Physics 534

(Revised Edition - 2000)

This Study Guide was written by a committee of Physics teachers to help students prepare for the Physics 534 theory/written examination.

The contents of the Guide are:

- **Problem-Solving Strategy**
- **Module 1: The Nature of Light**
- **Module 3: Mechanics**
- **Psst... You want to see the answers to the exam?**
- **Appendices: Equations and Table of Trigonometric Ratios**

The section on Problem-Solving Strategies presents students with examples of an effective strategy for answering constructed-response type questions.

The two Modules are presented in sections that cover one or more objectives of the program. These sections include *Key Concept*s, *Examples* and *Sample Question*s. The answers and solutions to the *Sample Questions* may be found at the end of the Guide. Objectives have occasionally been grouped together or presented in an order different from the MEQ program at the discretion of the authors.

The last section takes student through an entire examination, showing the reasoning steps that lead to the correct answers.

The Guide is designed as a study tool for students and is not to be considered as an official course program. For a more detailed description of the course content and learning activities, please refer to the document 16-3177A, Secondary School Curriculum *Physics 534: The Discovery of Matter and Energ*y, published by the Gouvernement du Québec, Ministère de l'Éducation 1992 ISBN: 2-550-23345-X.

1999-2000
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Feedback needed from Teachers!

In order to help the Science Action Plan Committee (SAPCO) make any necessary revisions to the Physics Study Guide, please complete the following questionnaire and return to the address below.

1. CONTENT

The content is adequate for:

Problem-Solving Strategies	**YES** ☐	**NO** ☐
Module 1	**YES** ☐	**NO** ☐
Module 3	**YES** ☐	**NO** ☐
Psst...You want the answers to the June exam?	**YES** ☐	**NO** ☐

I would suggest the following changes to:

Problem-Solving Strategies: ______________________________

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Module 1: ______________________________

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Module 3: ______________________________

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Psst...You want the answers to the June exam?: ______________________________

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Thank you for your assistance!

PROBLEM-SOLVING STRATEGY

This section is designed to present the student with examples of a highly effective strategy for answering "constructed response" type questions. The thought processes utilized in the execution of the following approach tend to enhance both the student's comprehension and step-by-step solving of multiple choice questions as well.

The student learns how to organize her/his thoughts about the content of each question. When this organized thinking is committed to paper, what results is a series of logical, connected steps needed to evaluate whatever is required to be solved in each question, whether qualitative or quantitative.

The following descriptions indicate the content to be included in each of **three sections** which the student completes to compile his/her best answer under the headings:

- **GIVEN**
- **REQUIRED**
- **SOLUTION**

GIVEN:

In this section, the student includes all information which she/he considers to be relevant.

Possible sources of such information include . . .

- the text of the question:
  - tables
  - graphs
  - diagrams

- authorized reference materials included in examination question booklets:
  - the list of formulas and quantities
  - table of trigonometric ratios

- the student's knowledge:
  - equations
  - accepted values for physical constants
  - appropriate laws and principles.

It is important to note that the student's ability to recognize **relevant information** will result in the exclusion of any information which is not actually needed to arrive at the best answer, even if such information is stated in the question.

This information-recognition process is essential to the student's comprehension of question content as well as his/her understanding of how information is connected through physical laws and principles.

REQUIRED:

This section is where the student identifies specifically what the question is asking her/him to find; its contents indicate how effectively the student has read and understood the question.

The student, therefore, identifies the unknown factor or value which is asked for in the question.

SOLUTION:

After the **connection** between what is **given** and what is **required** is established in the two previously-completed sections by the **selection of needed information** in the form of data, equations, and arguments.

The following steps of final execution are:

1. If necessary, the desired variable is isolated.
2. Given values are filled in with numbers and units of measurement separated if desired.
3. A check is made to ensure that the desired units of measurement will appear in the final answer.
4. Estimate the numerical value of the final answer. *[If it seems reasonable, proceed to the next step.]*
5. Carry out the specific mathematical operations needed.
6. If necessary (it frequently is), **round off** the numerical value **only at this final step.**

Note: *This **SOLUTION** section is the only section where mathematical operations are carried out in the case of questions that are quantitative in nature.*

*For questions which are not quantitative in nature, the **SOLUTION** section contains a series of logical statements (conclusions) needed to define or state the best answer.*

Following these steps and completing the three sections will reduce and even may eliminate certain types of errors. Causes of errors such as improper isolation of variables, omission of appropriate units of measurement, acceptance of unreasonable values due to lack of estimation, and developing improbable thought sequences can all be remedied to significant extents by the use of this “constructed-response” technique.

It is also quite likely that possible errors can be recognized more readily by the use of this step-by-step problem-solving strategy, and **corrected more effectively.** Practice of these techniques and the underlying strategy of careful development of the best answer will bring each student to a more clear understanding of the principles and laws of Physics. It will particularly help the student to modify his/her thought processing to optimum advantage for all questions, most directly those requiring answers of the "constructed-response" variety.

The following series of sample questions is included here (some in annotated form) to provide the student with a clear idea of how the benefits of this problem-solving strategy may be accessed. Questions from both modules – Optics and Mechanics – have been included along with their solutions stated step-by-step in the three sections described in the foregoing pages.

Some of the features that are important in the examples shown are:

- identification of each variable with a unique symbol
- clear statement of each relevant item of information
- the use of symbols and equations to clearly show the path to the best answer
- closing statement of the value or nature of the item(s) required.

Optics

Question 1 **The index of refraction for a ray of light travelling from air to quartz is 1.46. Calculate the angle of refraction for the ray of light if it is incident upon the quartz surface at an angle of 30°.**

	RELEVANT INFORMATION	SOURCE	COMMENTS
***Given*:**	Index of refraction of quartz, n = 1.46	• question text	• note the assigning of a symbol, n (more will follow)
	Angle of incidence of light ray, i = 30°	• question text	• assigned symbol, i
	$n = \frac{\sin i}{\sin R}$, where R represents the angle of refraction	• student's knowledge	• another assigned symbol What is it?
	sin i = sin 30° = 0.5000	• table of trig. ratios	• student's knowledge could be the source
***Required*:**	Find the value of: R.	• question text	
***Solution*:**	$n = \frac{\sin i}{\sin R}$		
	Multiply both sides by $\frac{\sin R}{n}$		
	$\sin R = \frac{0.5000}{1.46}$	• isolation	• step to determine sine of angle of refraction
	= 0.3425		
	0.3425 =sine of angle 20.02°	• table of trig. ratios	• could be from inverse operation on calculator Note rounding operation
	Angle of refraction in quartz, R = 20°		

Mechanics

Question 2 **A truck travelling along a highway at 90.0 km/h comes to a stop after a distance of 200.0 m. For how many seconds must the driver of the truck have applied the brakes in order to bring the truck to rest in the distance specified?**

	RELEVANT INFORMATION	SOURCE	COMMENTS
Given:	Speed of truck, $v_1 = 90.0$ km/h	• question text	• note the assigning of a symbol, v_1 (more will follow)
	Truck's final speed, $v_2 = 0$ km/h	• ...comes to a stop...	• assigned symbol, v_2
	Braking distance, $\Delta d = 200.0$ m	• question text	• assigned symbol, Δd
	Let Δt be braking time	• student's knowledge	• assigned symbol, Δt
	Average speed of truck, $v_{av} = \dfrac{(v_1 + v_2)}{2}$	• student's knowledge	• another assigned symbol. What is it?
	$v_{av} = \dfrac{\Delta d}{\Delta t}$	• formula sheet	• student's knowledge could be the source
	3.60×10^3 s = 1 h	• student's knowledge	• student realizes that the braking time is needed in seconds
	1.00×10^3 m = 1.00 km	• student's knowledge	• student is now set to change km/h to m/s
Required:	Find the value of Δt	• ...for how many seconds...	
Solution:	$v_1 = 90.0$ (km/h) x (1000 **m**/km)/(3600 **s**/h)	• math operation	• $\dfrac{\cancel{km}}{\cancel{h}} \times \dfrac{m}{\cancel{km}} \times \dfrac{\cancel{h}}{s}$
	= 25.0 m/s	• convert km/h to m/s	(note inversion on third item)
	$v_{av} = \dfrac{(v_1 + v_2)}{2} = \dfrac{(25.0 + 0)\text{m/s}}{2} = 12.5$ m/s	• math operation	• constant acceleration
	$v_{av} = \dfrac{\Delta d}{\Delta t}$		
	Multiply both sides by $\dfrac{\Delta t}{v_{av}}$		
	$\Delta t = \dfrac{\Delta d}{v_{av}} = \dfrac{200.0 \text{ m}}{12.5 \text{ m/s}} = 16.0$ s	• isolating desired variable	• student now has time factor expressed in terms of other values
	The braking time for truck is 16.0 s.		

Additional Problems in Optics and Mechanics

The following questions have been selected to provide further examples of the application of the problem-solving strategy outlined above. These examples will illustrate how this technique can be used by the student to answer a variety of questions from both modules and with varying levels of challenge to the student.

QUESTION 1

A numismatist (coin collector) is examining a newly-found coin. She uses a converging lens with a focal length of 10.0 cm.

How far in front the lens must the coin be placed if a virtual image of it must be formed at a distance of 30.0 cm in front of the lens?

Given: Distance of image, d_i = -30.0 cm *(Negative because of virtual image on same side as object)*
Focal length of lens, f = 10.0 cm

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$ where d_o is the object distance.

Required: Determine the value of d_o

Solution:

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$

$$-\frac{1}{d_i}, \frac{1}{d_o} = \frac{1}{f} - \frac{1}{d_i}$$ *(Subtract $\frac{1}{d_i}$ from both sides)*

Common denominator right side, $$\frac{1}{d_o} = \frac{(d_i - f)}{d_i\, f}$$

Invert, $$d_o = \frac{d_i\, f}{(d_i - f)}$$

$$d_o = \frac{-(30.0 \text{ cm})\,(10.0 \text{ cm})}{(-30.0 \text{ cm} - 10.0 \text{ cm})}$$

$$= \frac{(-300 \text{ cm}^2)}{(-40.0 \text{ cm})}$$

$= 7.50$ cm *(Note the retention of three significant digits to match the measurements cited in the question).*

The coin must be placed 7.50 cm in front of the converging lens.

QUESTION 2

A nature photographer is attempting to capture a 9.0 m tall giraffe on film. The animal is standing at a distance of 70.0 m from the photographer. What should be the focal length of the camera lens used if the image of the giraffe is to be 35 mm tall?

Given: Height of object, $h_o = 9.0$ m
Height of image, $h_i = -35$ mm *(inverted image)*
1.0×10^3 mm = 1.0 m
Distance from object to lens, $d_o = 70.0$ m

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

Magnification, $M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$

Required: Find f

Solution: $h_i = -35 \text{ mm} \times (1.0 \text{ m} / 1.0 \times 10^3 \text{ m}) = -0.035$ m *(common unit, metre)*

$$\frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

$$\frac{h_i\,(-d_o)}{h_o} = d_i$$ *(Multiply both sides of the equation by -d_o)*

$$d_i = \frac{-0.035 \text{ m } (-70.0 \text{ m})}{9.0 \text{ m}}$$ *(Negative value for inverted image)*

$$= 0.272 \text{ m}$$

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

Common Denominator Right side, $\frac{1}{f} = \frac{(d_i + d_o)}{d_i d_o}$

Invert, $f = \frac{d_i d_o}{(d_i + d_o)}$

$$f = \frac{(0.272 \text{ m} \times 70.0 \text{ m})}{(0.272 \text{ m} + 70.0 \text{ m})}$$

$$= \frac{19.04 \text{ m}^2}{70.272 \text{ m}}$$

$$= 0.271 \text{ m}$$

The focal length of the camera should be 0.27 m.

QUESTION 3

Two thin lenses combine to form an effective lens system. The lenses have focal lengths of 5.0 cm and -8.3 cm respectively. Determine the focal length of the lens system.

Given: Focal length of first lens, $f_1 = 5.0$ cm

Focal length of second lens, $f_2 = -8.3$ cm

1.0×10^2 cm = 1.0 m

Power of first lens, $P_1 = \frac{1}{f_1}$ *(Note that focal length must be expressed in metres.)*

Power of second lens, $P_2 = \frac{1}{f_2}$

Power of lens system, $P_t = P_1 + P_2$

Focal length of lens system, $f_t = \frac{1}{P_t}$

Required: Determine the value of f_t

Solution:

$$f_1 = 5.0\text{ cm} \times \frac{1.0\text{ m}}{1.0 \times 10^2\text{ cm}} = 0.050\text{ m}$$

$$f_2 = -8.3\text{ cm} \times \frac{1.0\text{ m}}{1.0 \times 10^2\text{ cm}} = -0.083\text{ m}$$

$$P_1 = \frac{1}{0.050\text{ m}} = 20\text{ dioptres}$$

$$P_2 = \frac{1}{-0.083\text{ m}} = -12\text{ dioptres}$$

$$P_t = 20\text{ dioptres} + (-12\text{ dioptres}) = 8\text{ dioptres}$$

$$f_t = \frac{1}{8}\text{ dioptres} = 0.125\text{ m}$$

Focal length of the lens system is 0.125 m or 12.5 cm.

QUESTION 4

A hiker walks with a velocity of 2.0 m/s due east. Her friend leaves the same starting position at the same time, but walks with a velocity of 3.0 m/s due north. Determine the distance that will separate the two friends after 5.0 s have passed.

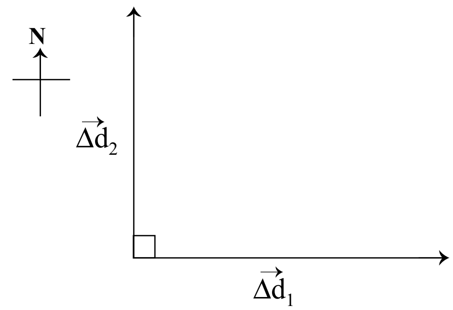
Given: Velocity of hiker, $\vec{v}_1 = 2.0$ m/s due east

Velocity of friend, $\vec{v}_2 = 3.0$ m/s due north

Displacement of hiker, $\vec{\Delta d}_1 = \vec{v}_1 \times \Delta t$

Displacement of friend, $\vec{\Delta d}_2 = \vec{v}_2 \times \Delta t$

Time for displacements, $\Delta t = 5.0$ s



Directions of displacements form a right triangle, *(North and east are 90º apart)*

therefore,

Distance separating friends after five seconds,

$\Delta d = \sqrt{(\Delta d_1^2 + \Delta d_2^2)}$ *(Pythagoras' theorem)*

Required: Find the value of Δd

Solution: $\Delta d_1 = (2.0 \text{ m/s}) \times 5.0 \text{ s} = 10 \text{ m}$ due east

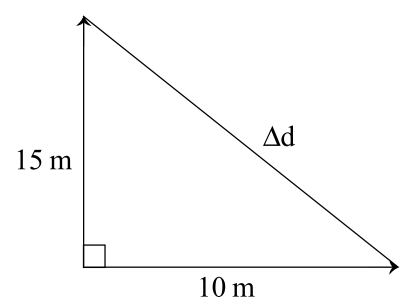
$\Delta d_2 = (3.0 \text{ m/s}) \times 5.0 \text{ s} = 15 \text{ m}$ due north

$$\Delta d = \sqrt{(10 \text{ m})^2 + (15 \text{ m})^2}$$

$$= \sqrt{100 \text{ m}^2 + 225 \text{ m}^2}$$

$$= \sqrt{325 \text{ m}^2}$$

$$= 18.03 \text{ m}$$

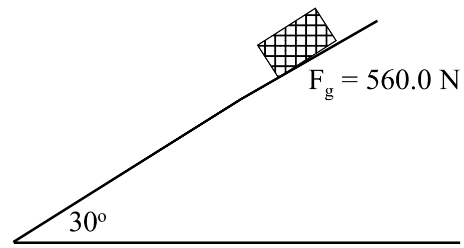


Distance separating friends after five seconds is 18 m.

(NB. This question is not a 'vector addition' so the vectors are <u>not</u> drawn 'tip-to-tail')

QUESTION 5

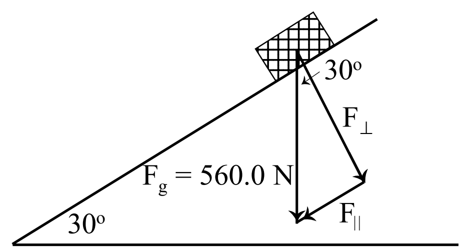
A trunk weighing 560.0 N is resting on an plane inclined at an angle of 30.0° above the horizontal. Find the magnitude of the parallel component of the trunk's weight.



Given: Weight of trunk, $F_g = 560.0$ N
Angle of inclined plane, $\theta = 30.0°$
Sine $\theta = F_{||} / F_g$, where $F_{||}$ is the parallel component of the trunk's weight
Sine $\theta = 0.5000$ *(From tables or calculator)*

Required: Find $F_{||}$

Solution: Sine $\theta = F_{||} / F_g$
F_g sine $\theta = F_{||}$
$F_{||} = 560.0 \text{ N} \times 0.5000 = 280.0$ N



The magnitude of the parallel component of the weight of the trunk is 280.0 N

QUESTION 6

A skydiver jumps from an aircraft at an altitude of 1.500×10^3 m. Determine her downward displacement during a freefall that lasts 10.0 s.

Given: Acceleration due to gravity, $g = 9.8 \text{ m/s}^2$
Time interval for freefall, $\Delta t = 10.0$ s
Skydiver's initial downward velocity, $v_1 = 0$ m/s

Skydiver's displacement, $\Delta d = \cancelto{0}{v_1 \Delta t} + ° \, g \, \Delta t^2$ *(Since v_1 equals 0)*

Required: Find the value for Δd

Solution: $\Delta d = ° \, (9.8 \text{ m/s}^2)(10.0 \text{ s})^2 = (490 \text{ m/s}^2)(\text{s}^2) = 4.90 \times 10^2$ m

Skydiver's freefall displacement is 490 m [down]

QUESTION 7

What power must an elevator motor develop in order to raise the elevator and its contents through a distance of 30.0 m in 60.0 s. The mass of the elevator and its contents is 1.50×10^3 kg.

Given: Mass of elevator and contents, $m = 1.50 \times 10^3$ kg
Displacement of elevator, $\Delta d = 30.0$ m
Time for elevator displacement, $\Delta t = 60.0$ s
Acceleration due to gravity, $g = 9.8$ m/s^2
Weight of elevator and contents, $F_g = mg$
Work done by elevator motor, $W = F\,\Delta d = F_g\,\Delta d$ *(applied force is equal and opposite to the weight)*
Power of elevator motor, $P = W / \Delta t$
$1\text{ N} = 1\text{ kg} \cdot \text{m/s}^2$
$1\text{ N} \cdot \text{m} = 1\text{ J}$
$1\text{ W} = 1\text{ J / s}$

Required: Determine the value of P

Solution: $F_g = 1.50 \times 10^3\text{ kg} \times 9.8\text{ m/s}^2 = 1.47 \times 10^4\text{ kg} \cdot \text{m/s}^2$
$W = (1.47 \times 10^4\text{ N})\ (30.0\text{ m}) = 4.41 \times 10^5\text{ N} \cdot \text{m}$

$$P = \frac{4.41 \times 10^3\text{ J}}{60.0\text{ s}} = 7.35 \times 10^3\text{ J/s}$$

The power of the elevator motor is 7.35×10^3 W

MODULE 1 (OPTICS)

1. PROPAGATION OF LIGHT **1.1 Light Sources and Phenomena**

Show how light is transmitted by referring to light phenomena you have observed in your environment.

§ 1.1: pp. 1-3.

Key Concepts:

1. **Luminous** - materials that can emit light. Example: sun
2. **Non-luminous** objects can only be seen by reflected light. Example. Moon

Types of Light Sources:

1. **Incandescent** - materials emit light when heated to a high temperature. Example: stove element
2. **Luminescent** - light is emitted through a reaction with little or no heat released. Example: 'light sticks' that release light when bent.
3. **Fluorescent** - materials release light because of the absorption of high energy radiation. Example: fluorescent lights
4. **Phosphorescent**- similar to fluorescent except that light continues to be emitted after the source of radiation has been removed. Example: translucent green toys (stars etc.) that glow green once the lights have been shut off.

Light Phenomena:

1. **Reflection** - light bouncing off surfaces. Example. Mirrors
2. **Refraction** - light rays may be bent when they travel from one substance to another. Example. A pebble on the bottom of a lake is not where is seems to be.
3. **Diffusion** - we can see light rays through dust when some of the light rays are scattered.
4. **Dispersion** - a piece of cut glass when suspended in front of a window can cause a rainbow to appear.
5. **Diffraction** - light spreads or bends as it passes through a small opening or around the edge of a barrier. Example: appearance of street lights when viewed through a window screen.
6. **Absorption** - light energy is absorbed into objects, especially black objects.

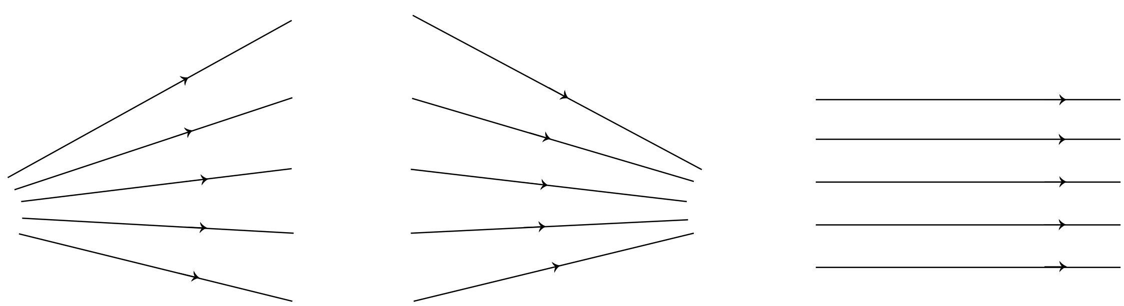
1. PROPAGATION OF LIGHT **1.2 Transmission of Light**

Describe the behaviour of light by observing in the laboratory.

§ 1.3 pp. 4-6.

Key Concepts:

1. Linear propagation - light travels in straight lines
2. Ray - the path taken by light energy. We depict these as lines on paper (see diagrams a-c below)
3. Ray diagrams - using more than one ray to depict a converging, diverging or parallel beam of light.
4. Diverge - light rays become farther apart (see diagram a)
5. Converge - light rays go closer together (see diagram b)
6. Parallel rays - rays travel the same distance apart (see diagram c)



a) diverging rays b) converging rays c) parallel rays

1. PROPAGATION OF LIGHT **1.2.2 Pinhole cameras**

Observe the behaviour of light through laboratory experiments.

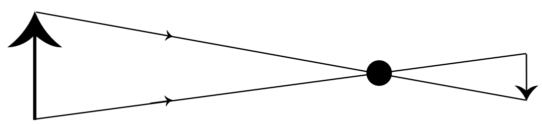
§ 1.3 pp. 4-9

Key Concepts:

1. Camera obscura, also known as a pinhole camera demonstrates that light travels in straight lines.

2. An image is formed upside down on the screen at the back of the camera

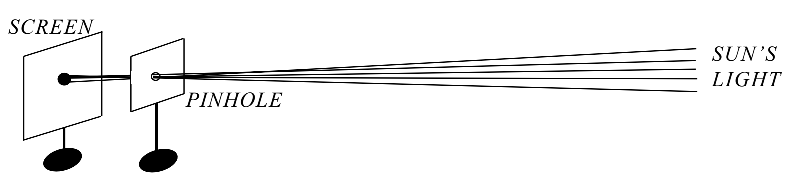
3. Since light travels in straight lines, the image within a pinhole camera will be inverted, and smaller than the object. In order to make the image larger the object must be placed closer to camera.



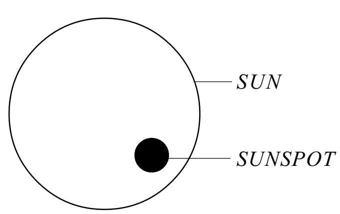
Object observed with pinhole camera *Image on screen of pinhole camera*

SAMPLE QUESTION

1. *To avoid causing damage to her eyes, Virginia observed a sunspot by having the sun's light pass through a pinhole and observing it on a screen as shown here :*



If the sunspot is observed directly (not through a pinhole) it appears as shown below :



In which position will the sunspot appear on the screen?

1. PROPAGATION OF LIGHT — 1.3 Shadow Formation

Illustrate the formation of the umbra and penumbra using diagrams.

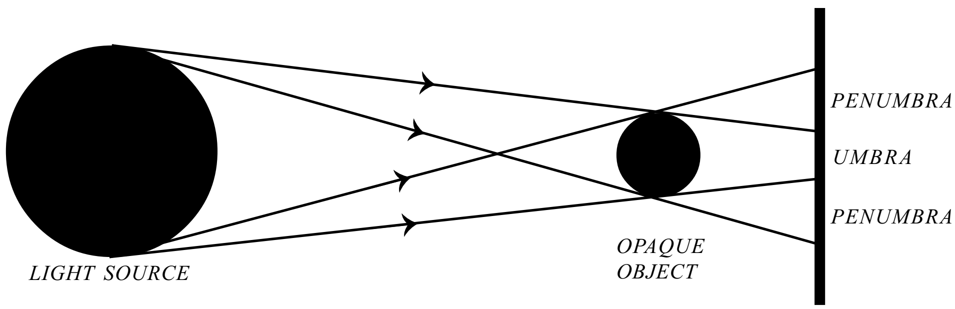
§ 1.4 pp. 6-7

Key Concepts:

1. Umbra - the area of total shadow, this areas receives no light.

2. Penumbra - the area of partial shadow, this area receives some light.

3. Application - solar and lunar eclipses

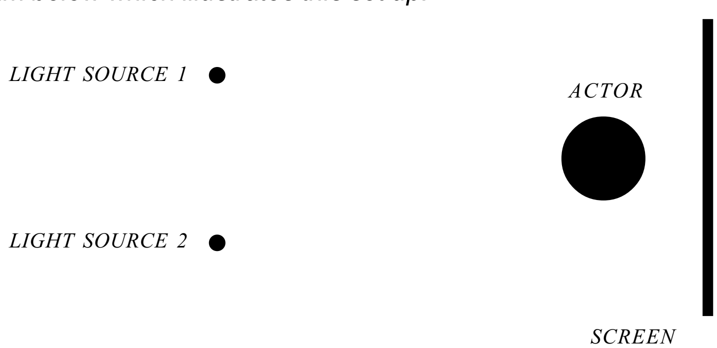


These four rays define the areas.

SAMPLE QUESTIONS

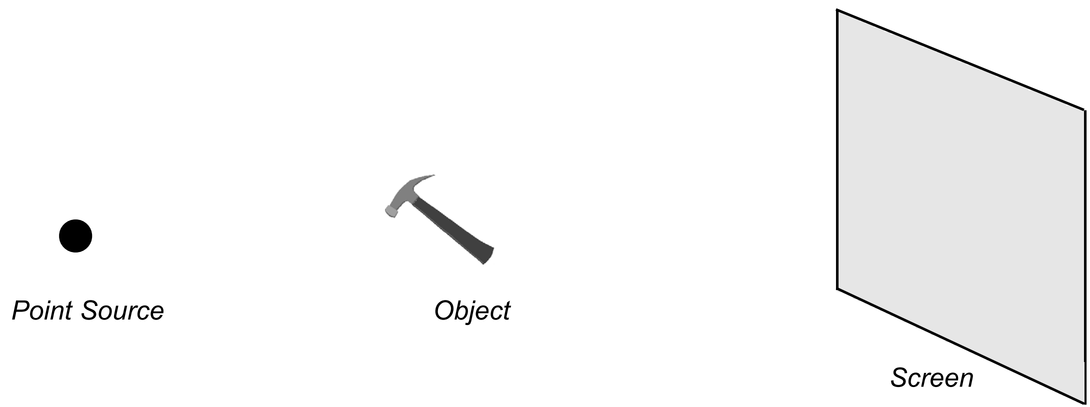
1. *An actor is giving a performance.*

   Two spotlights are set up in such a way that they can be considered as acting as one light source. Look at the diagram below which illustrates this set up.



Using the diagram above, draw a ray diagram and label the umbra and the penumbra, if applicable.

2. *A point source illuminates an object placed in front of a vertical screen.*



Proportionally speaking, which of the following diagrams best represents the shadow of this object?

A)

B)

C)

D)

2. LAWS OF REFLECTION — 2.1 Reflection of Light

Analyze the behaviour of light reflected from mirrors of different shapes.
Identify reflected light in your environment.

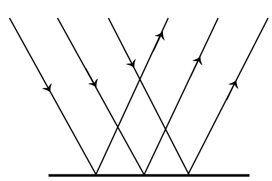
§ 2.1 pp.17-20

Key Concepts:

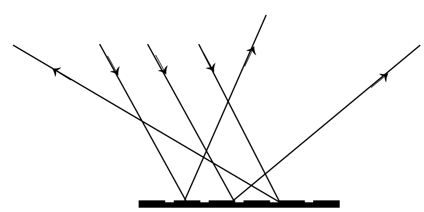
1. **Reflection**: everyone has experienced reflections of light. Every morning we look at ourselves in the mirror before we leave the house. Reflection occurs when a light beam travelling through one medium (air) hits a barrier (water) where the light beam is turned back into the air.

2. **Specular Reflection** - this is considered the regular type of reflection. Polished, flat surfaces allow parallel light rays to bounce back parallel. This occurs with mirrors, or on a calm lake.

3. **Diffuse reflection -** many surfaces that we would consider flat are actually uneven when viewed under a microscope, for example a piece of paper. Paper reflects light, however the light rays that bounce back are not parallel.



Specular reflection:
the rays are parallel



Diffuse reflection:
the rays are not parallel

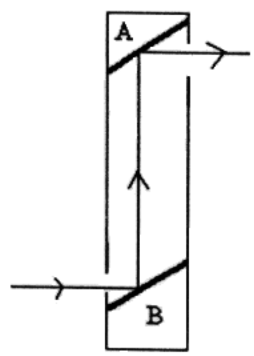
2. LAWS OF REFLECTION 2.2 Devices using Mirrors

Demonstrate the operation of a device containing one or more mirrors, using diagrams.

§ 2.2 pp.18-20

Key Concepts:

1 Many devices use mirrors to channel light to where it is needed. The Museum of Art in Ottawa uses natural lighting by directing light from outside through the use of mirrors. Cameras use a mixture of mirrors and lenses to position light so you can see through the viewfinder what the picture you are taking will look like. Periscopes use mirrors so you can see around corners.



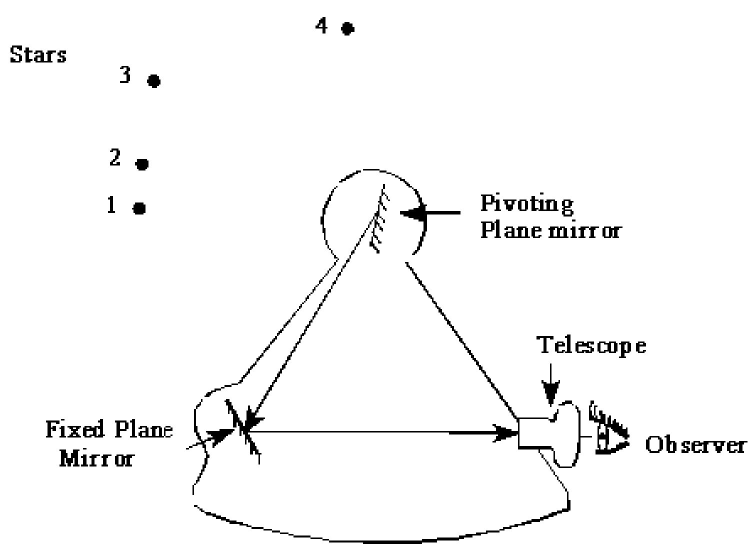
At A and B, mirrors are placed at 45 degree angles to reflect light. Periscopes are found on submarines and golf courses.

2 See-through mirrors allow light to be reflected back but some of it is allowed through. Depending on which side of the mirror you are standing, you will either see through the mirror (more light is transmitted) or see your reflection (more light is reflected).

SAMPLE QUESTION

1. *The sextant illustrated below has been set to view the image of only one of the four stars shown in the diagram.*

   Which star can be observed? Give reasons for your answer.



2. LAWS OF REFLECTION **2.4 Plane Mirrors - Laws of Reflection**

Describe the behaviour of light reflected from a plane mirror, after conducting experiments.

§ 2.4 pp. 23-24

Key Concepts:

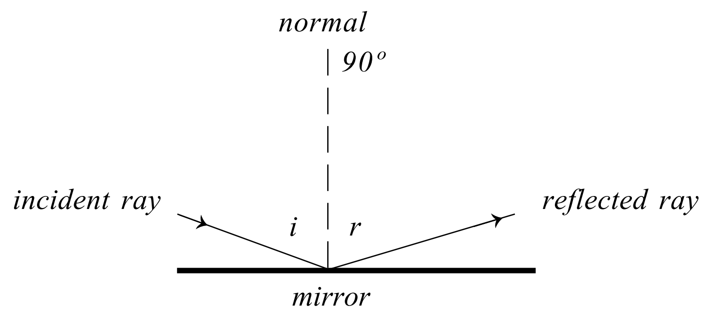
1. **Laws of Reflection -**
   First Law: The angle of incidence is equal to the angle of reflection. (i = r)
   Second Law: The normal, the incident ray and the reflected ray all lie in the same plane.

2. **Incident ray:** the ray of light approaching the mirror.

3. **Reflected ray:** the ray of light reflected away by the mirror.

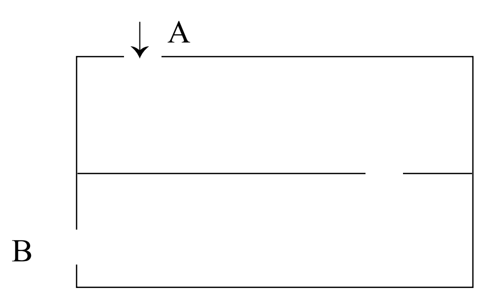
4. The **point of incidence** is where the incident rays strikes the mirror.

5. The **normal** is the line that forms a 90^{o} angle to the reflecting surface at the point of incidence.



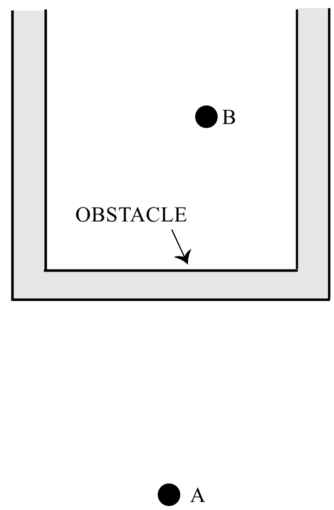
SAMPLE QUESTIONS

1. The diagram below represents a box through which light is to pass from opening A to opening B. Several small plane mirrors are available.



How would you place the mirrors in the box so that the light passes from A to B?

2. *You must bypass an obstacle in order to direct a laser beam from point A to point B. This situation is illustrated below. You are going to do this using several small plane mirrors.*



How will you position these small mirrors so that you can direct the laser beam from point A to point B?

Your answer must contain the following elements:

- *draw the laser beam;*
- *draw each mirror;*
- *identify each angle of incidence by **i** and each angle of reflection by **r.***
- *give the measure of each of these angles.*

2. LAWS OF REFLECTION — 2.5 Field of Vision

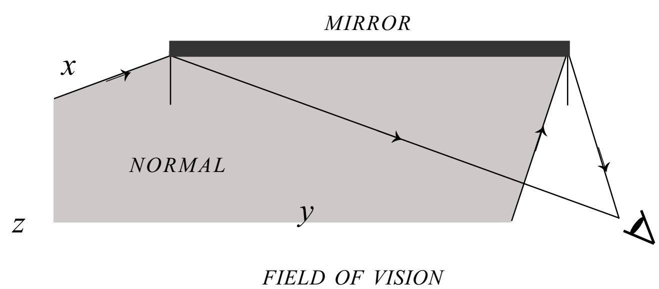
Determine the field of vision of an observer facing a mirror, after conducting experiments.

§ 2.5 pp.24-25

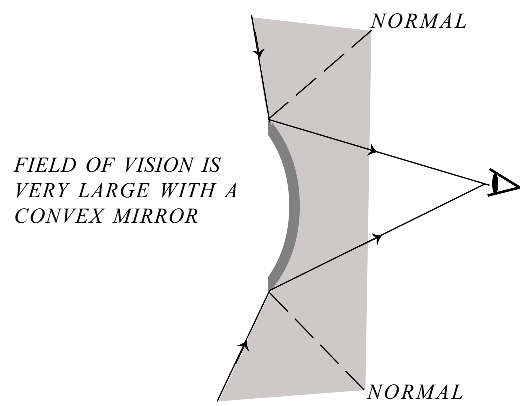
Key Concepts:

1. Our view in a mirror depends on how we position ourselves in front or to the side of the mirror.

2. The **field of vision** can be determined through ray diagrams:
   a. Draw two normals, one at either end of the mirror,
   b. Draw an incident ray from your eye to each normal.
   c. Draw a reflected ray from each normal.
   d. Remember the laws of reflection when drawing both sets of rays (i = r)



Note: An object placed at x could not be seen by this person, but if objects were placed at y or z, they would be easily seen.

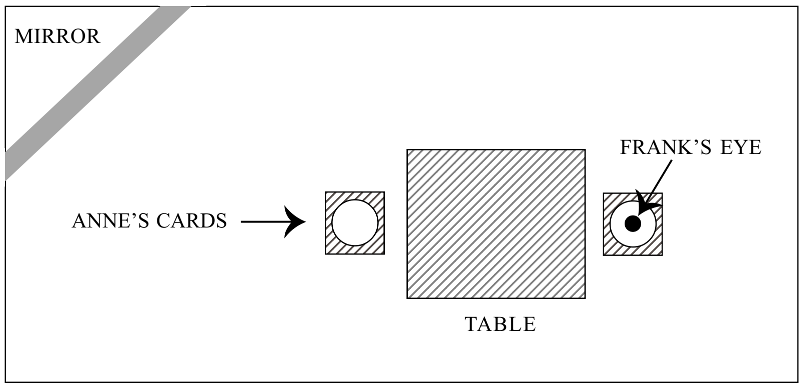


3. Convex mirrors are used in department stores and on buses because of their large field of vision.

SAMPLE QUESTION

1. *A plane mirror is placed vertically in the corner of a room. Frank and Anne are playing cards in this room.*

   This situation is illustrated below.



According to this diagram, can Frank see Anne's cards using the mirror?

Explain your answer by drawing the ray diagram that correctly shows Frank's field of vision.

2. LAWS OF REFLECTION **2.6 Curved Reflectors**
2.10 Problem Solving Related to Ray Diagrams

Analyze the behaviour of light reflected from a curved mirror.

Analyze light reflected from mirrors of different shapes, by solving problems and doing exercises involving ray diagrams.

§ 2.6 pp. 25-30

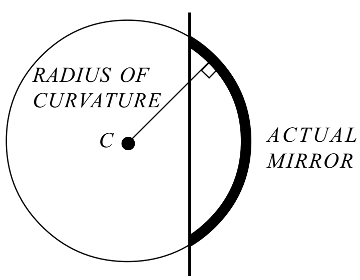
Key Concepts:

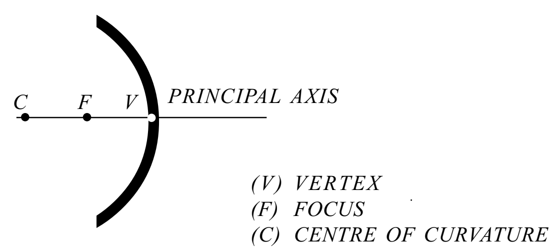
1. The laws of reflection still apply to curved mirrors even though the images look different from plane mirrors.

2. The **centre of curvature** (C) is to be found at the centre of a curved mirror. The mirrors used are parts of spheres so the centre of curvature is located in the direct centre of the sphere if the mirror were complete.

3. The **radius of curvature** is a line drawn perpendicular from the surface of the mirror to the centre of curvature.

4. The centre of the curved surface of the mirror is called the **vertex** (V). The **principal axis** joins the centre of curvature and the vertex.





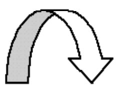
5. Four rays are very important when determining the location of an image in a concave mirror:
   a) Any ray parallel to the principal axis will reflect through the focus.
   b) A ray along the principal axis will reflect directly back along the principal axis.
   c) A ray going through the focus and striking the mirror will reflect parallel to the principal axis.
   d) Any ray through C will reflect back on itself.

6. Parallel rays approaching a **concave mirror** will go through the focus. This type of mirror is called a converging mirror

7. Parallel rays approaching a **convex mirror** will diverge away from the mirror as if originating from a focus behind the mirror.

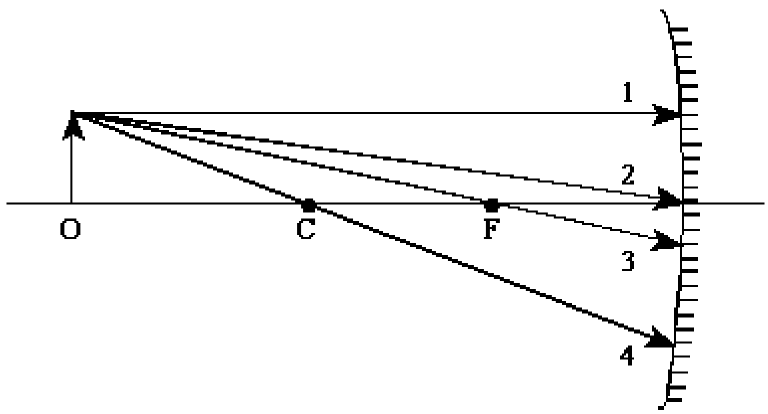
8. One device that takes advantage of concave mirrors is a car headlight. The lamp is placed at the focus so the light rays are beamed out parallel along the principal axis. Telescopes work in the opposite manner. They collect parallel beams of light from far away and focus them to form an image at the focus.

9. Convex mirrors are used for security reasons because of their large field of vision. They are also used on the driver side of many motor vehicles for this same reason.



SAMPLE QUESTION

1. An object O is placed in front of a concave spherical mirror. Four light rays from the tip of the object strike the mirror, as illustrated below.



Draw the reflected rays for all 4 incident rays.

3. LAWS OF REFRACTION **3.1 Refraction of Light**

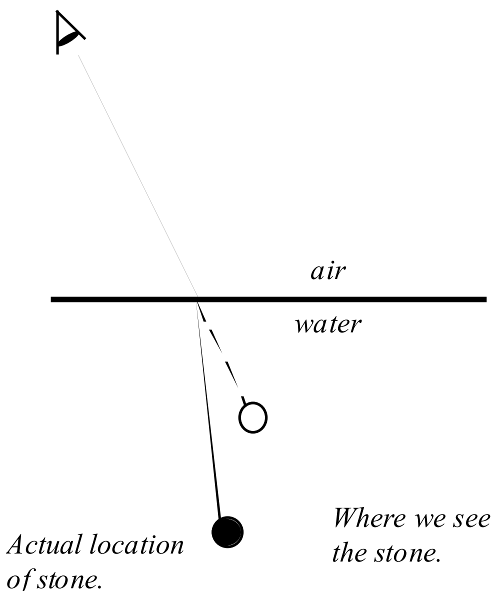
Analyze the behaviour of light refracted by different substances, by referring to their observations of light phenomena in their environment and to laboratory experiments they have conducted. Identify everyday examples of refracted light.

§ 3.1 pp.44-45.

Key Concepts:

1. Refraction – light changes direction when it reaches a boundary between media of two different optical densities. A medium is any substance that light can travel through. Examples – water, air, glass, mineral oil.

2. Everyday examples of refraction are:
   a) a spoon bending when placed in a glass of water
   b) you try to pick up a stone off the bottom of a lake and you miss it because its actual location is over a bit from where you see it
   c) a glass ornament hanging in front of a window causes a rainbow to be formed
   d) a rainbow after it rains



SAMPLE QUESTIONS

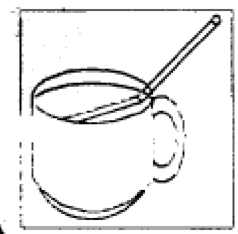
1. *Which illustrations correspond to each of the phenomena listed below?*

   Write the letter of the illustration on the corresponding numbered line of the phenomenon.

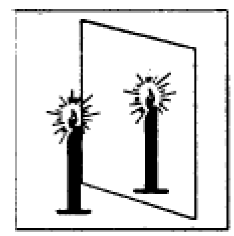
Illustrations

Phenomena

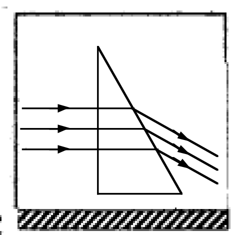
1. *Specular reflection*
2. *Diffuse reflection*
3. *Refraction*



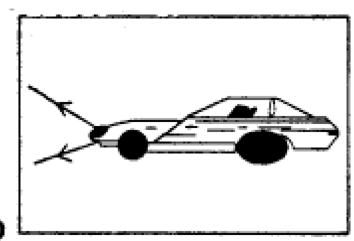
A



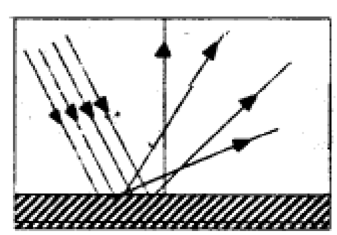
B



C



D



E

2. *Among the following situations, select those that are examples of the refraction of light.*

1) *The moon is visible at night because the sun's light returns to us from the moon's surface.*

2) *A ray of light strikes the surface of a rectangular prism obliquely. It leaves the opposite side parallel to the incident ray.*

3) *A ray of light becomes visible in a smoke-filled room.*

4) *A stick half submerged in water at an oblique angle appears to be bent at the surface of the water.*

5) *When we look at the surface of a lake in the calm of autumn, we see the colourful inverted image of the trees located near the opposite bank.*

6) *A ray of white light strikes the surface of a triangular prism and emerges from the other side as a coloured spectrum.*

A) ***1, 3, 5***	***B)*** ***1, 4, 5***
C) ***2, 3, 6***	***D)*** ***2, 4, 6***

3. LAWS OF REFRACTION	**3.2 Behaviour of Refracted Light**

Show how light refracted by optical objects behaves, using diagrams.

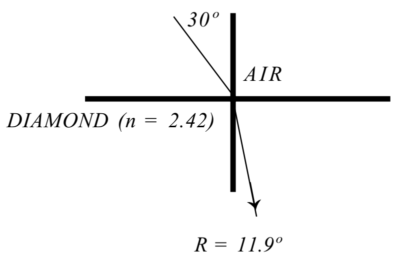
§ 3.2 pp. 46-48

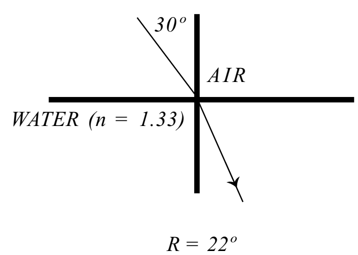
Key Concepts:

1. Light travelling from a less dense medium into a more dense medium will refract closer to the normal. When light enters the denser medium it slows down and changes direction. This only occurs when light strikes a boundary obliquely. Light rays that are perpendicular to the surface boundary will travel straight through the second medium until it reaches a new boundary.

2. Light travelling from a denser medium into a less dense medium will refract farther away from the normal.

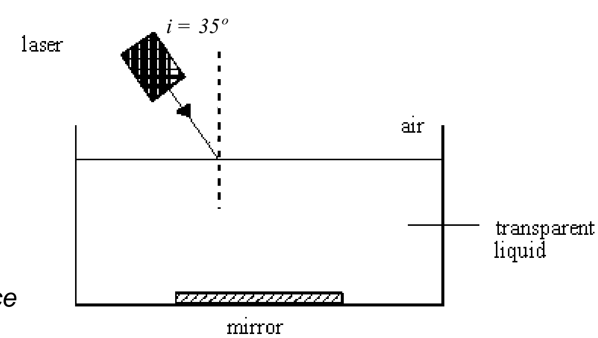
3. The terms denser or less dense refer to optically dense. This term is used when "referring to the medium in which the speed of light decreases". (§ p. 60)





SAMPLE QUESTION

1. *You are given the equipment shown.*



The laser emits a ray of red light. Show the path followed by the ray of light from the time it strikes the surface of the liquid until it re-enters the air.

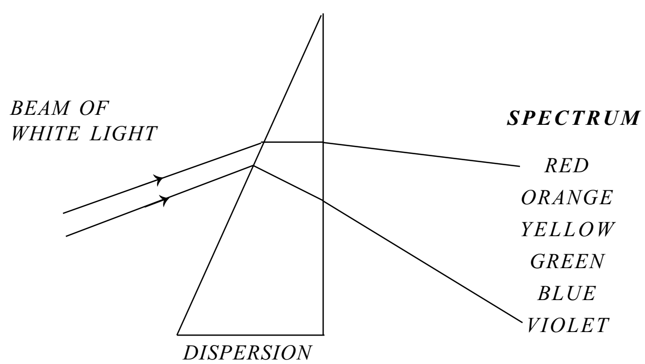
3. LAWS OF REFRACTION **3.3 Light and Color**

Propose a model of light that explains how they perceive the colour of objects in their environment.

§ 3.3 pp.48-53

Key Concepts:

1. **Dispersion** – White light is made of a range of wavelengths of light. Six different colours are identified in this range of wavelengths. They all travel through media at a different speed and therefore when white light changes medium (hits a barrier) each colour of light refracts differently. The result is a **Spectrum** of coloured light consisting of Red, Orange, Yellow, Green, Blue, and Violet. (ROYGBV). A prism of glass when placed at the correct angle will cause this to happen.

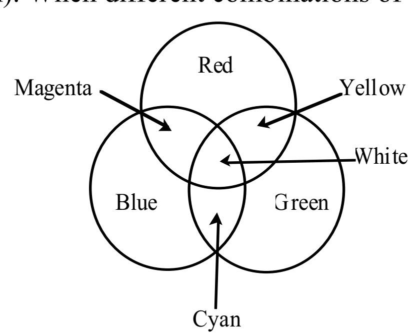


2. **Recomposition** – a prism of glass can also cause all the wavelengths of light to refract back into one large beam of white light.

3. Other methods causing recomposition of light are:
   a) a series of mirrors placed at the appropriate angle.
   b) a Newton disc painted with various colours, when spun quickly, appears off-white.

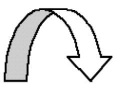
4. Rainbows are an example of dispersion that is viewed after a rain. Look carefully and you can see a secondary rainbow with the colours reversed from the first. Water droplets in the air cause white light to refract and disperse. (§ p. 50)

5. Colour perception (addition). When different combinations of wavelengths of light enter the eye we see different colours.



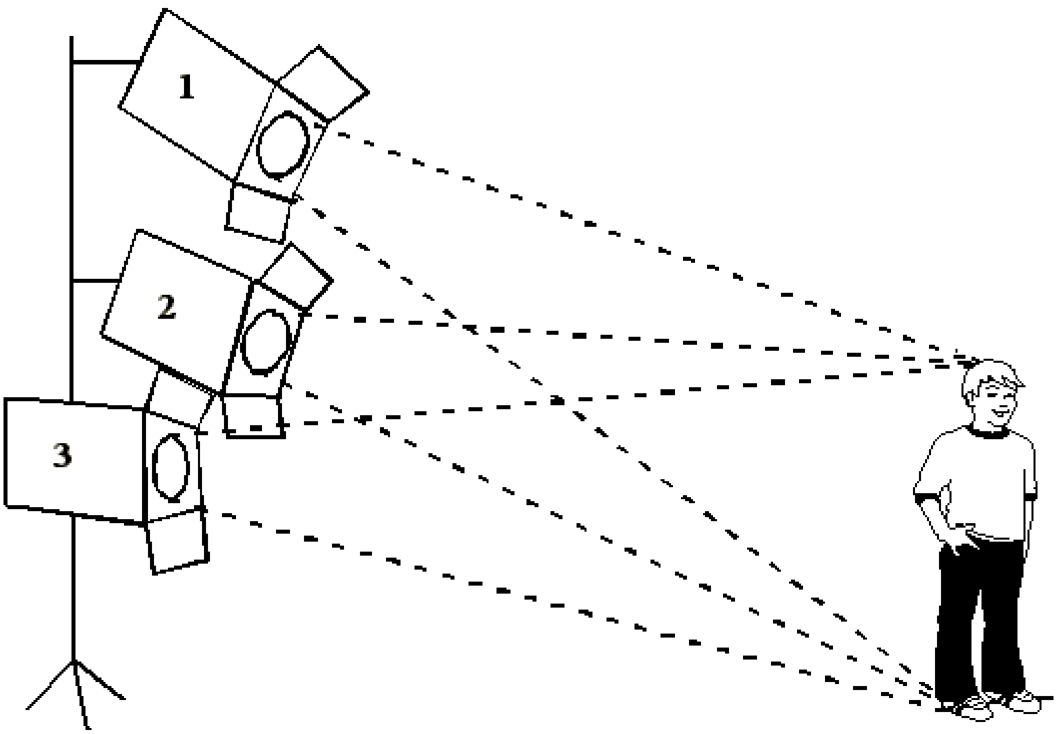
6. Colour perception (subtraction). If a coloured filter is placed over a lightbulb only the colour of the filter will pass through. All the other wavelengths are absorbed.

   A T-shirt is blue because it reflects blue light. The dye pigments absorb most of the light but reflect the blue. Viewed in other than blue light the T-shirt will appear ‘black’ as all the light is absorbed.



SAMPLE QUESTIONS

1. A lighting director uses three spotlights in succession to illuminate a singer from head to foot. Each spotlight emits a different colour of light.



- When the lighting director uses only spotlight 1, the singer’s sweater appears blue and his pants appear black.
- When he uses only spotlight 2, his sweater appears red and his pants appear black.
- When he uses only spotlight 3, his sweater appears green and his pants appear green.

If the lighting director used only one white spotlight, what colours would the singer’s sweater and pants appear to be?

2. *A desktop appears to be coloured blue when illuminated by white light.*

Which of the following is an explanation of this phenomenon?

A) ***The desk refracts the blue light and absorbs nearly all colours.***
B) ***The desk disperses the white light and transforms it mainly to blue light.***
C) ***The desk absorbs most of the blue light and reflects the other colours in all directions.***
D) ***The desk absorbs the blue light poorly and reflects it in all directions.***

3. LAWS OF REFRACTION **3.4 Index of Refraction**

Determine the index of refraction for transparent substances, after conducting laboratory experiments.

§ 3.4: pp. 60-64

Key Concepts:

1. Index of Refraction - light rays travelling from a less dense medium into a more dense medium will change direction closer to the normal. As the angle of incidence (i) decreases, so does the angle of refraction (R). The relationship that exists between i and R is seen in Snell's Law:

$$n = \frac{\sin i}{\sin R}$$

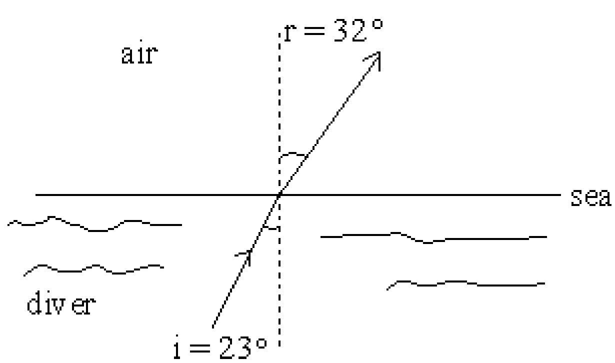
n = index of refraction
sin i = sine of the angle of incidence
sin R = sine of the angle of refraction

The index of refraction is a ratio which is a constant for any two transparent media. The absolute index of refraction of a medium is determined when light travels from a vacuum into the medium.

Example: the index of refraction of water $n = \frac{\sin i}{\sin R} = \frac{\sin 30^\circ}{\sin 22^\circ} = 1.33$

SAMPLE QUESTION

1. *An under-water diver directs a beam of light as shown in the diagram below.*



What is the refractive index of the seawater, to two decimal places?

3. LAWS OF REFRACTION 3.7 Total Internal Reflection and the Critical Angle

Analyze totally internally reflected light, after conducting experiments.

§ 3.8 pp. 71-73

Key Concepts:

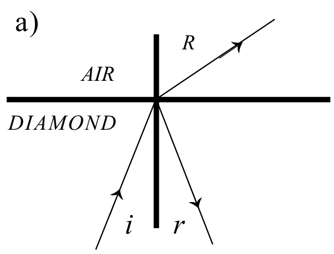
1. **Total internal reflection** occurs when light is leaving a denser medium and is travelling into a less dense medium, for example from diamond to air. This only occurs when the incidence angle is greater than the **critical angle**. The critical angle is a constant between two media.

   a) Incident angles less than the critical angle will result in a refracted ray.

   b) Incident angles equal to the critical angle will result in a critical ray of 90 °.

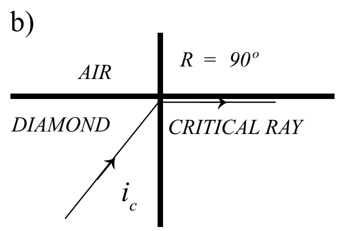
   c) Incident angles greater than the critical angle will result in a reflected ray into the denser medium.

a)



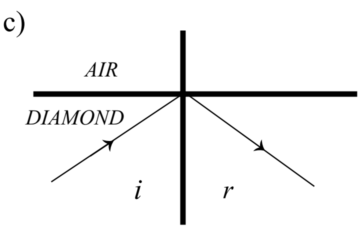
REFRACTION AND INTERNAL REFLECTION

b)



AT THE CRITICAL ANGLE

c)



TOTAL INTERNAL REFLECTION

To calculate the critical angle for any substance set the angle of refraction to 90 °

.

(See section 3.8 for an explanation of the following equation).

Example: The light ray is travelling from diamond ($n_1 = 2.42$) to air ($n_2 = 1.0003$)

$$n_1 \sin i_c = n_2 \sin R$$

$$2.42 (\sin i) = 1.0003 (\sin 90^\circ)$$

$$2.42 (\sin i) = 1.0003 (1.0)$$

$$2.42(\sin i) = 1.0003$$

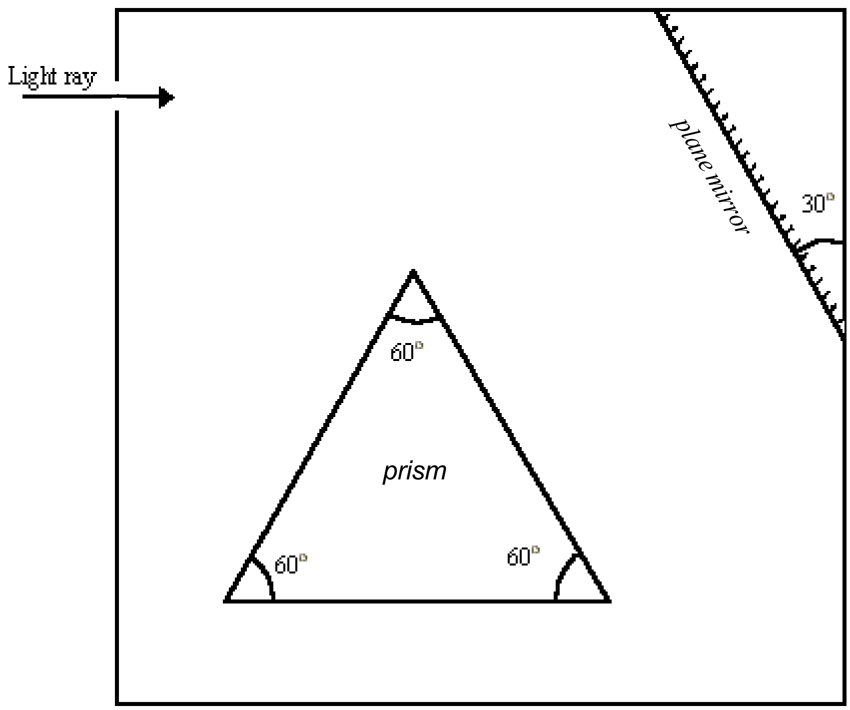
$$\sin i = \frac{1.0003}{2.42} = 0.4133 \qquad i = 24.4^\circ$$

The critical angle for diamond is 24.4°. Any incident angle larger than this will result in total internal reflection.

Examples where total internal reflection occurs:
a) fiber optics
b) diamonds are enjoyed for their "sparkle"

SAMPLE QUESTION

1. *Illustrated below is the inside of a closed box. There is one hole through which a light ray enters as shown.*



$n_{air} = 1.0$

$n_{prism} = 2.54$

Where should a second hole be placed in order for the light ray to exit the box?

You must show the complete path of the light ray to find your answer. Show all your work.

3. LAWS OF REFRACTION	3.8 Problem Solving Related to Refraction

Analyze situations in which light is refracted by different substances, by solving problems and doing numerical exercises involving graphical solutions.

§ 3.8 pp. 72-73

Key Concepts:

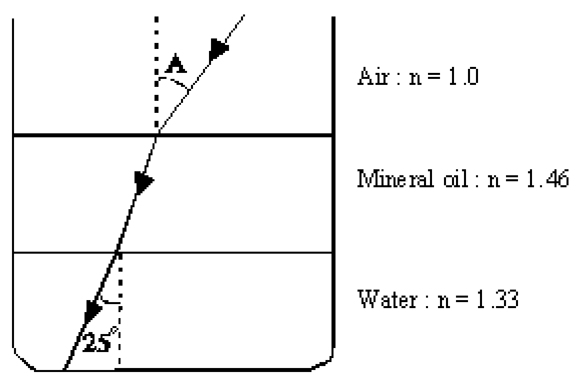
1. Calculations of either the index of refraction, the angle of incidence or the angle of refraction can be determined using the equation below. In most cases one of the media is not a vacuum and therefore both indexes of refraction must be considered.

$$n_1 \sin \Theta_1 = n_2 \sin \Theta_2$$

n_1 = the index of refraction of the medium the ray is travelling out of
n_2 = the index of refraction of the medium the ray is travelling into
Θ_1 = the angle of incidence
Θ_2 = the angle of refraction

SAMPLE QUESTION

1. *In the laboratory, a light ray passes through two liquids, one floating on top of the other, in a beaker. The angle of refraction in the water is 25°.*



What is the value of the angle of incidence A?

4. LENSES **4.1 Devices that use Lenses**

The students will learn how to analyze the characteristics of lenses on the basis of what they have learned about the behaviour of light while doing scientific work. Illustrate the operation of a device containing one or more lenses using diagrams.

§ 4.1: pp. 84-86.

Key Concepts:

1. Converging lens and a combination of lenses are used in:
   a) magnifying glasses (burning glasses)
   b) microscopes
   c) telescopes
   d) overhead projectors
   e) cameras
   f) spotlights

2. Converging lenses can be used to condense the light (e.g. in a slide projector to illuminate a slide uniformly).

3. Microscopes – use converging lenses to magnify objects.

4. LENSES	**4.2 Types of Lenses**

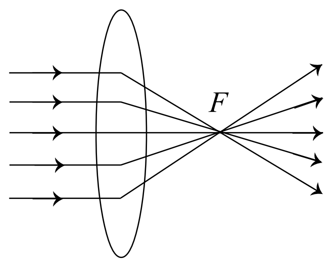
Differentiate among different types of lenses, after observing objects through them.

§ 4.2: pp. 86-88.

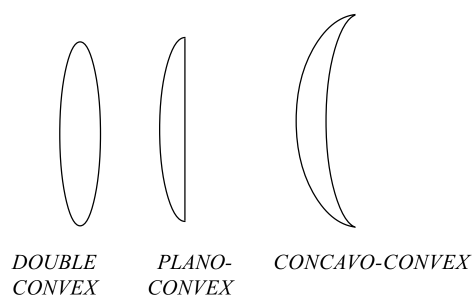
Key Concepts:

There are two types of lenses:

1. Converging or Convex lenses – are thickest in the middle and become thinner on the edges. Parallel rays of light directed through a convex lens will cause the rays to converge at a point called the focus.



Types of Convex lenses:

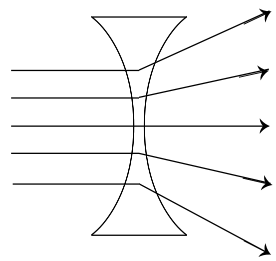


Example:
Double convex lenses are the most common in a school – used in classroom experiments, also in magnifying glasses

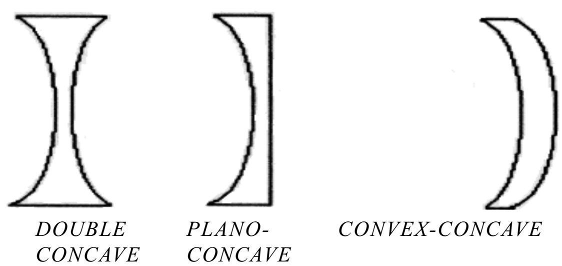
Plano-convex lenses are used as condensers, and
Concavo-convex lenses are used in eye glasses.

2. Diverging or Concave lenses – are thinnest in the middle and become thicker on the edges.

Parallel rays of light directed through a concave lens will cause the rays to diverge or spread apart as if coming from a point behind the lens.



Types of Concave (Diverging lenses)



Example: Camera lenses and eye glasses

4. LENSES **4.3 Refraction in Lenses**

Analyze the behaviour of light refracted by lenses, after conducting experiments.

§ 4.3 pp. 88-91

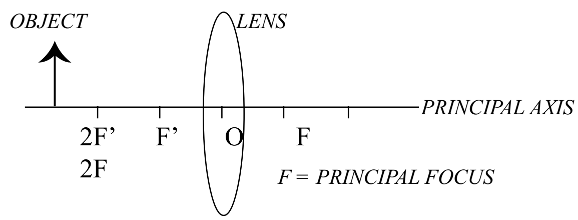
Key Concepts:

<u>Lens Terminology</u>

1. **Optical Centre** (O) – geometric centre of the lens.

2. **Principal Axis** – a line drawn through **O** and perpendicular to the lens surface.

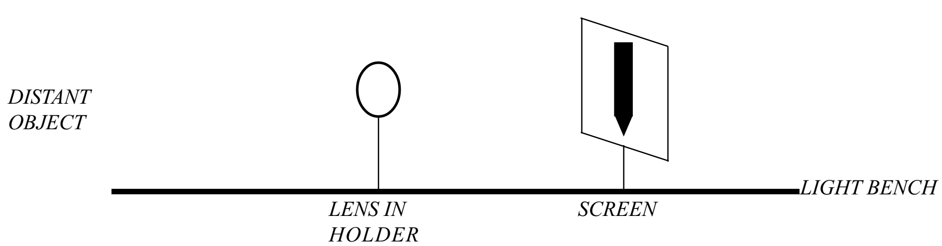
3. **Principal Focus** (F) – a distant light source will emit rays that when they refract through the converging lens will converge at the Principal Focus. When a screen is placed at **F**, a clear image is observed.



4. **Focal length** (f) – distance between **O** and **F**. The focal length for a converging lens is positive. The opposite is true for a diverging lens.

5. To determine the focal length of a converging lens through an experiment:

   Use a distant object, such as the view through a window. Move screen back and forth until the image is clear. Measure the distance from the lens to the screen.



6. Power and Focal length – the thicker lens has a higher power but a smaller focal length (see Objective 4.4).

4. LENSES	**4.4 Optical Power of a System of Lenses**

Determine the optical power of a lens system, after conducting experiments.

§ 4.4 pp. 91-93.

Key Concepts:

1. The **power** of the lens is the inverse of the focal length. Power is measured in **dioptres** (δ or *d*) and focal length is measured in metres.

   $$P = \frac{1}{f}$$

   Example: Find the power of a converging lens with a focal length of 10 cm.
   Given f = 10 cm = 0.01 m

   $$P = \frac{1}{0.10\ m}$$

   $$P = 10\ d$$

2. The power and focal length of a diverging lens is negative.

   $$P = -2.0\ d \rightarrow f = -50\ cm$$

3. **Combination of lenses** - the power of lens combinations can be added directly. If only the focal lengths are given, they have to be converted to power first.

   $$P_t = P_1 + P_2 + ... + P_n$$

   Example: Three lenses with focal lengths of 50 cm, -10 cm and 5 cm are placed together. These convert to 0.5 m, -0.10 m and 0.05 m. Find the total focal length of the combination of lenses.

   $$P = \frac{1}{0.50\ m} \rightarrow 2\ d$$

   $$P = -\frac{1}{0.10\ m} \rightarrow -10\ d$$

   $$P = \frac{1}{0.05\ m} \rightarrow 20\ d$$

   $$P_t = 2\ d + -10\ d + 20\ d = 12\ d$$

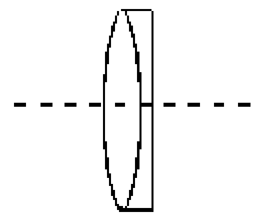
The total power of the combination of lenses is 12 d and the focal length of the combination is:

$$f = \frac{1}{12\ d} = 0.083 \text{ m}$$

The focal length of the combination of lenses is 8.3 cm. The total power must be calculated first before the total focal length.

SAMPLE QUESTIONS

1. *A lens combination consists of a converging lens and a diverging lens. The focal length of the lens combination is 50 cm. The focal length of the converging lens is 20 cm. What is the optical power of the diverging lens?*



2. *You want to make a camera lens using a lens combination. This camera lens must have a focal length of 50 mm. You have five lenses whose optical powers are given in the table below.*

Lens	*Optical Power (dioptres)*
1	–10
2	–6.0
3	4.0
4	14
5	16

Find one possible lens combination that will enable you to make your camera lens.

4. LENSES	**4.6 Problem Solving Related to Lenses**

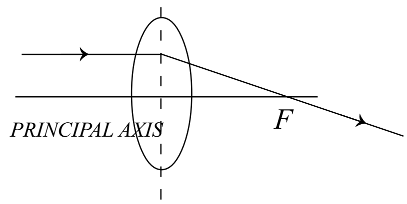
Analyze situations in which light is refracted by lenses of different shapes, by solving problems and doing exercises.

§ 4.5 pp. 93-95

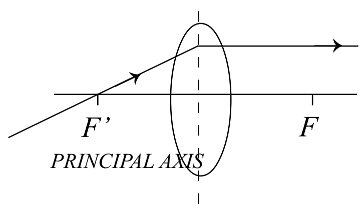
Key Concepts:

Rules for Rays in Converging Lenses

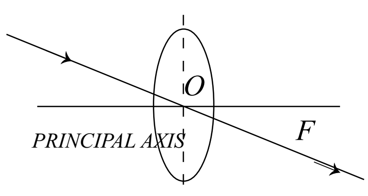
1. Draw a ray parallel to the principal axis. The ray will refract through the principal focus.



2. Draw a ray through the secondary Principal focus. It will refract parallel to the Principal axis.

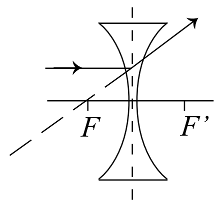


3. Draw a ray through the optical centre. It continues straight through the lens.

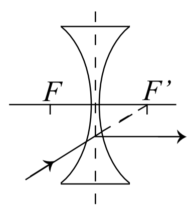


Rules for Rays in Diverging Lenses

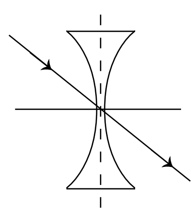
1. Draw a ray parallel to the principal axis. The ray will diverge away but can be traced back through the secondary focus.



2. Draw a ray through the lens to the principal focus. It will refract at the lens parallel to the princi pal axis, however, it can be traced to the principal focus.

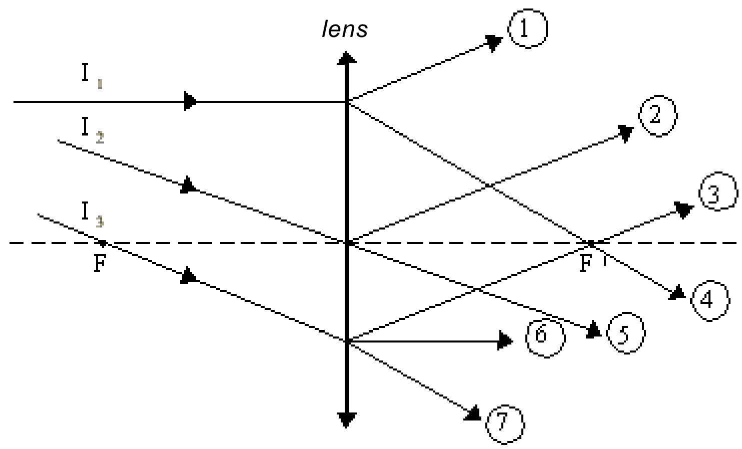


3. Draw a ray through the optical centre. It continues straight through the lens.



SAMPLE QUESTION

1. *The incident rays I_1, I_2 and I_3 strike the convex lens illustrated below.*



Choose the correct refracted rays.

5. IMAGES **5.1 Images formed by Converging Lenses**

Determine the characteristics of images formed by converging lenses, after conducting experiments.

§ 5.1 pp. 100-105

Key Concepts:

Note: In Ray diagrams - solid lines represent real objects and real images, dotted lines represent virtual objects and images.

To locate an image in a converging lens:

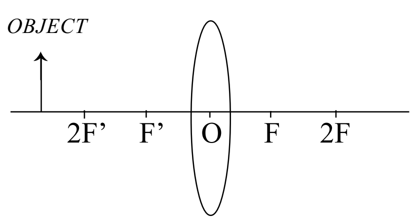
1. From the top of the object, draw a ray parallel to the principal axis, this refracts through the principal focus.

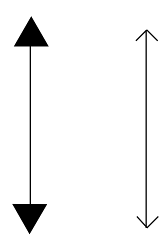
2. From the top of the object, draw a ray through the optical centre. This ray does not refract.

3. From the top of the object, draw a ray through the secondary focus and this refracts parallel to the principal axis.

4. Where the refracted rays intersect, draw the image. Remember if the object is touching the principal axis, so will the image. See § p. 104 for diagrams.

F	=	primary focus
F’	=	secondary focus
2F	=	twice the distance of the primary focus
2F’	=	twice the distance of the secondary focus
O	=	optical centre





5. Converging lenses can be drawn in three different ways - an oval or a double headed arrow.

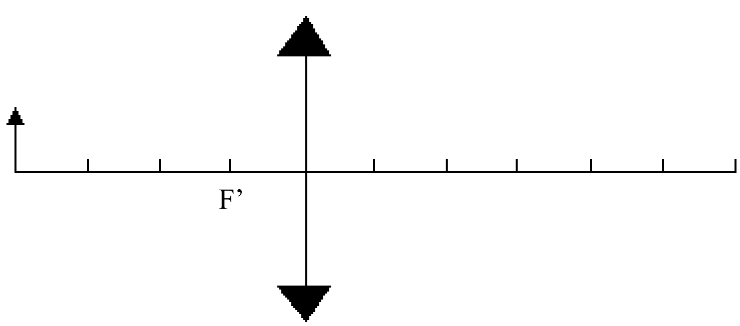
6. **Characteristics of images formed in converging lenses:**

Location of Object	**Location of Image**	**Size of image in relation to object**	**Real or Virtual**	**Inverted or Upright**
Beyond 2F’	Between F and 2F	Small	Real	Inverted
At 2F’	At 2F	Same size	Real	Inverted
Between 2F’and F’	Beyond 2F	Larger	Real	Inverted
At F’	NO IMAGE			
Between F’ and O	Behind object (d_i is negative)	Larger	Virtual	Upright

One practical application of placing a light source at F’ is a spotlight.

SAMPLE QUESTION

1. *The diagram below represents an object and a converging lens.*



Knowing the focal point of the lens, state two characteristics of the image formed by this system.

5. IMAGES **5.2 Images formed by Converging Mirrors**

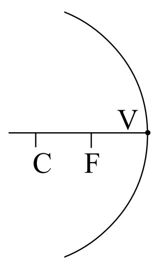
Determine the characteristics of images formed by a concave mirror, after conducting experiments.

§ . 5.4 pp. 110-111

Key Concepts:

1. To locate an image in a converging mirror:
   a) From the top of the object, draw a ray parallel to the principal axis, the rays reflect through the focus.
   b) From the top of the object, draw a ray through F to the top of the object, reflects parallel to the principal axis.
   c) Draw a ray along the principal axis and the ray reflects directly back along the same path.

2. Where the reflected rays intersect: draw the image. Remember if the object is touching the principal axis, so will the image. See § p. 113 for diagrams.



C = CENTRE OF MIRROR
F = FOCUS
V = VERTEX

3. **Characteristics of images formed in converging mirrors:**

Location of Object	Location of Image	Size of image in relation to object	Real or Virtual	Inverted or Upright
Far beyond C	at F	Smaller	Real	Inverted
Beyond C	Between C and F	Smaller	Real	Inverted
at C	At C	Same size	Real	Inverted
Between C and F	Beyond C	Larger	Real	Inverted
at F	NO IMAGE			
Between F and V	Beyond mirror	Larger	Virtual	Upright

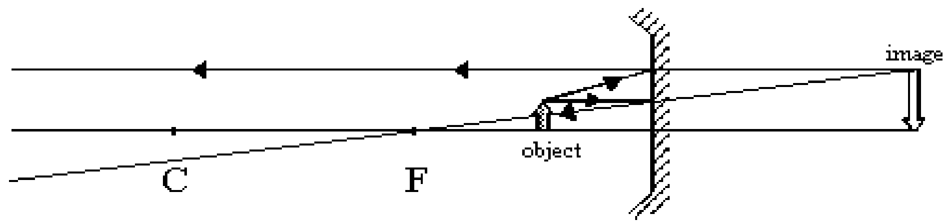
4. One practical application of placing a light source at F is a head light; the rays will reflect back parallel to the principal axis.

5. $\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$ This equation is also used with mirrors (see 5.7)

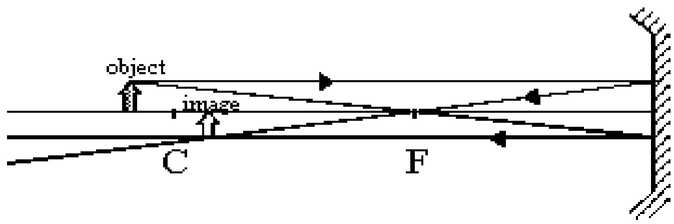
SAMPLE QUESTIONS

1. *In the following diagrams, identify those in which the object and its image formed by the concave mirror are correctly drawn. If the diagrams are incorrect, state one change that will make the diagrams correctly drawn.*

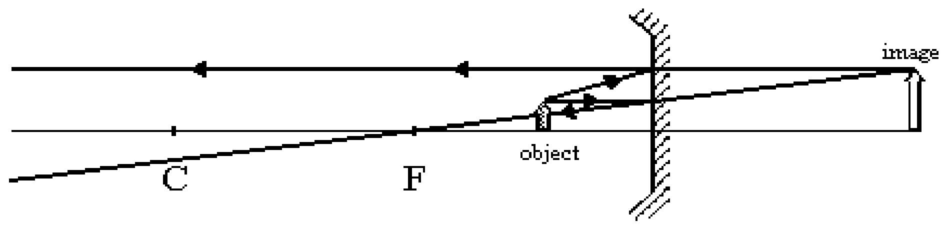
1



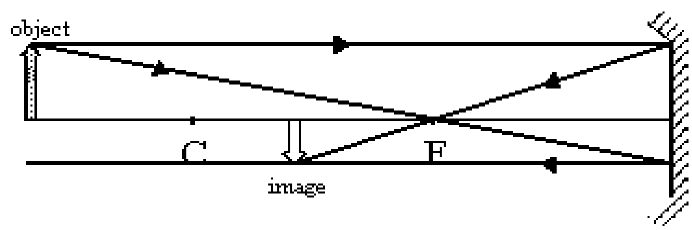
2



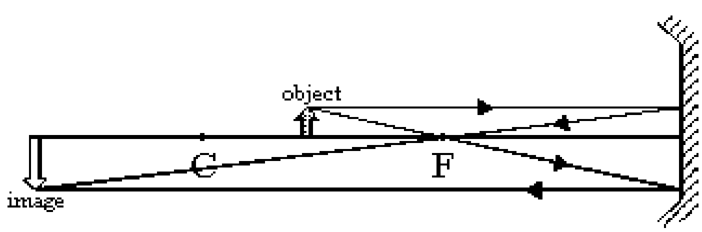
3



4

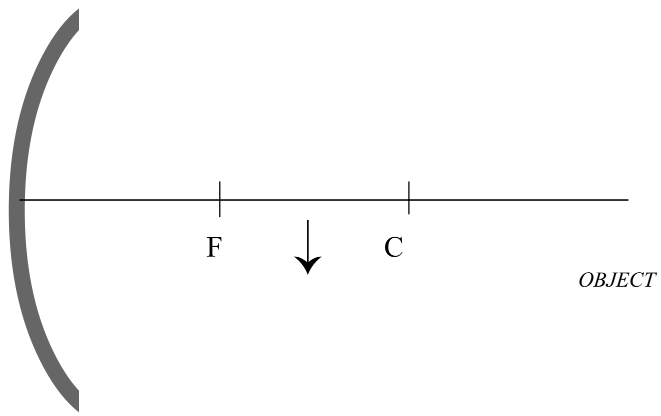


5



2. *You want to project a real image of an object using a concave mirror. This object is placed below the principal axis of the mirror.*

The diagram below illustrates the situation.



Locate and draw the image by means of an appropriate ray diagram.

5. IMAGES **5.3 Images formed by Diverging Lenses**

Determine the characteristics of images formed by diverging lenses, after conducting experiments.

§ 5.2 pp. 105-107.

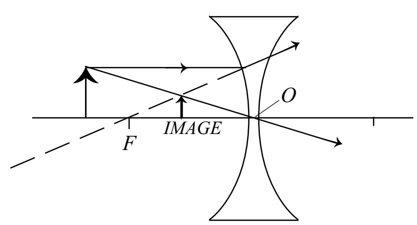
Key Concepts:

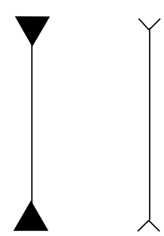
To locate an image in a diverging lens:

1. From the top of the object, draw a ray parallel to the principal axis, this refracts up and away from the lens, but extends through the principal focus.

2. From the top of the object, draw a ray through the optical centre of the lens. This ray does not refract. (see 4.6)

3. Where the refracted rays intersect, draw the image. Remember if the object is touching the principal axis, so will the image. See § p. 107 for a diagram.
   F = primary focus
   O = optical centre





4. Diverging lens can be drawn in three different ways - see in the above diagrams.

5. Characteristics of images formed in diverging lenses:

Location of Object	Location of Image	Size of image in relation to object	Real or Virtual	Inverted or Upright
For all positions of the object	Between F and O	Smaller	Virtual	Upright

SAMPLE QUESTION

1. *An object 2.0 cm high is placed in front of a diverging lens of focal length 1.8 cm. The object is 2.7 cm from the optical centre of the lens.*

   What are the four characteristics of the image of this object?

5. IMAGES	5.4 Images formed by Diverging Mirrors

Determine the characteristics of images formed by a convex mirror, after conducting experiments.

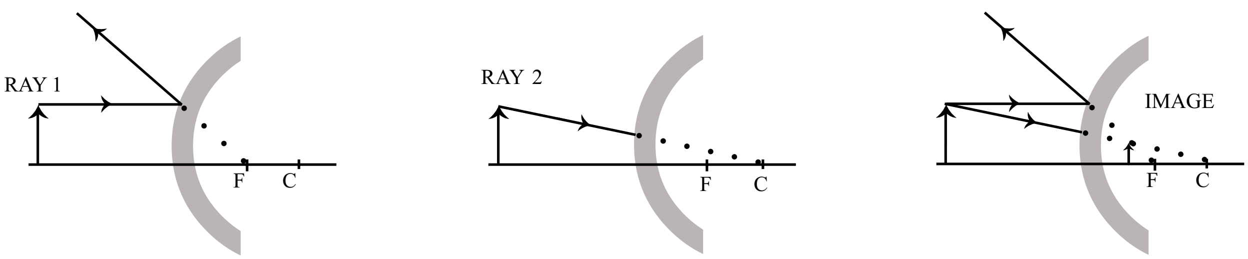
§ 5.6 pp. 116-118.

Key Concepts:

To locate an image in a diverging mirror:

1. From the top of the object, draw a ray parallel to the principal axis, this reflects away but can be traced back through the focus.

2. Draw a ray appearing to travel through the centre, which is then reflected back along the same path.



C = CENTRE OF MIRROR
F = FOCUS

3. Where the reflected rays intersect, draw the image. Remember if the object is touching the principal axis, so will the image. See § p. 117 for diagrams.

Note: The virtual focus is on the opposite side of the mirror to the reflective surface.

4. **Characteristics of images formed in diverging mirrors:**

Location of Object	Location of Image	Size of image in relation to object	Real or Virtual	Inverted or Upright
For all positions of the object	Between F and V	Smaller	Virtual	Upright

SAMPLE QUESTIONS

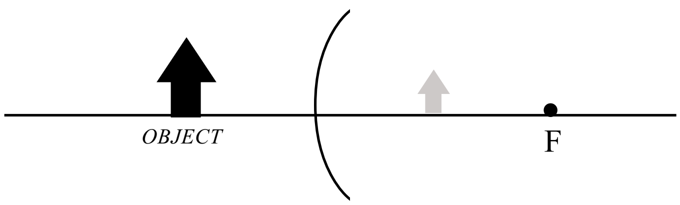
1. *For improved safety, convex mirrors are used on delivery trucks.*

   State two characteristics of the images formed by these mirrors.

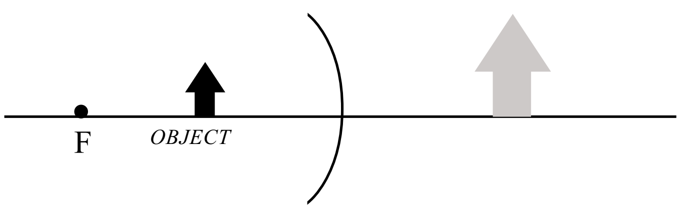
The following questions are based on Objectives 5.1 - 5.4

2. *Which one of the following diagrams does* ***NOT*** *correspond to reality?*

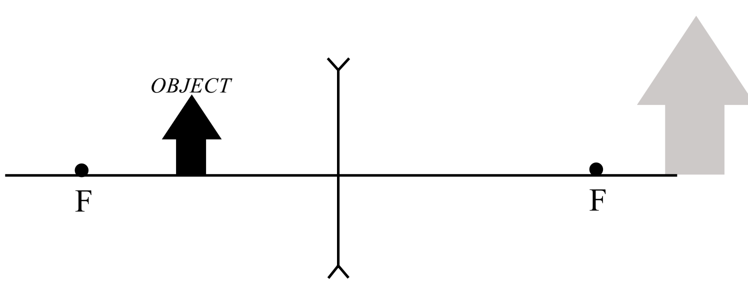
A)



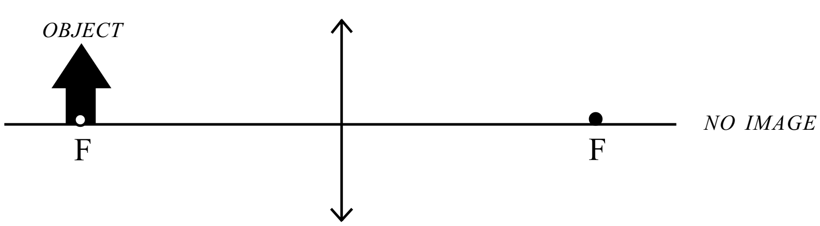
B)



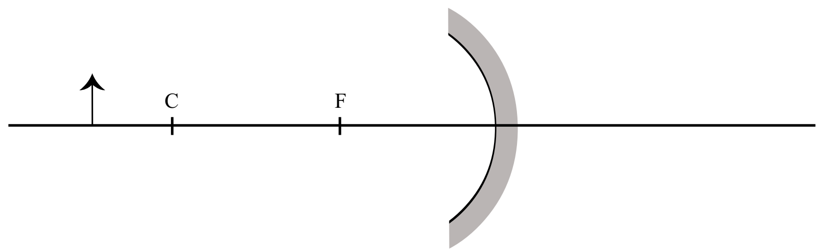
C)

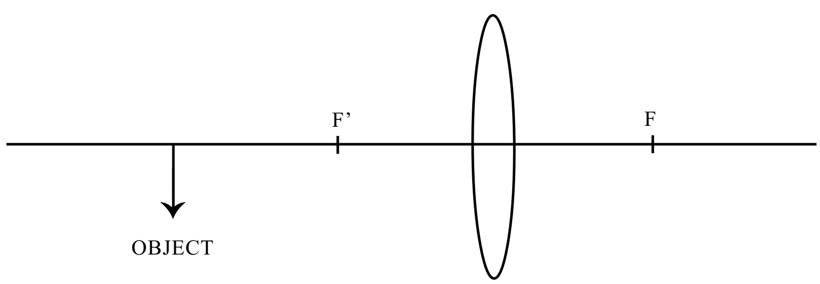


D)



3. *Draw ray diagrams for the following situations in order to determine the location of the image formed in each case.*





5. IMAGES	5.5 Images formed by Plane Mirrors

Determine the characteristics of images formed by a plane mirror, after conducting experiments.

§ 5.7 pp. 118-122.

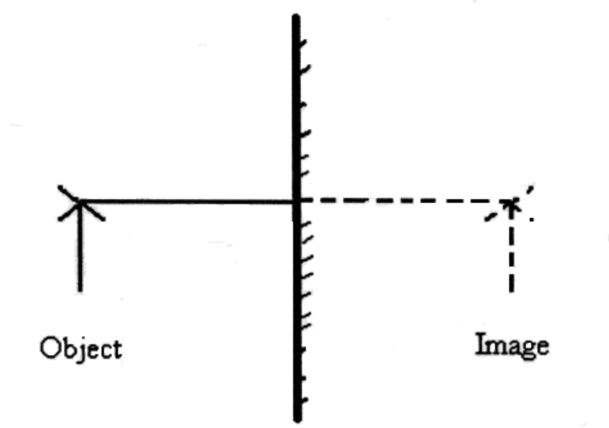
Key Concepts:

1. Image is always virtual and behind the reflective surface of the mirror.

2. $d_o = -d_i$.

3. The magnification is one (M = 1). The image is the same size as the object and always virtual.

4. The image is upright but laterally inverted.



SAMPLE QUESTION

1. *You put an object in front of a plane mirror. Which statement* ***correctly*** *describes the characteristics of the image?*

   A) ***The image is real, upright, smaller than the object and located in front of the mirror.***

   B) ***The image is real, inverted, the same size as the object and located in front of the mirror.***

   C) ***The image is virtual, inverted, larger than the object and located behind the mirror.***

   D) ***The image is virtual, upright, the same size as the object and located behind the mirror.***

5. IMAGES **5.7 The Thin Lens Equation**

Determine the mathematical relationships among the characteristics of images formed by a lens, on the basis of measurements made in the laboratory.

§ 5.1 pp. 102-103.

5.13 Problem Solving (graphical and mathematical) Related to Images in Lenses and Mirrors

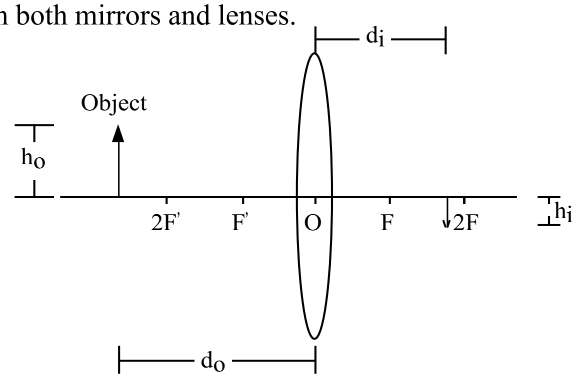
Analyze the characteristics of images formed by optical objects (mirrors, lenses) by solving problems and doing graphical and numerical exercises.

§ 5.3 pp. 107-110, 113-116.

Key Concepts:

1. The Thin Lens Equation can used with both mirrors and lenses.

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$$



d_o = the distance from the object to the optical centre (O)

d_i = the distance from the optical centre (O) to the image

f = focal length of the lens (positive for converging lenses, negative for diverging lenses)

2. The magnification of an image is determined using the following equations:

$$M = \frac{h_i}{h_o} \qquad \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

M = magnification

h_o = the height of the object

h_i = the height of the image

d_o = the distance from the object to the optical centre (O)

d_i = the distance from the optical centre (O) to the image

These formulas in part 2 can be used with:

a) pinhole cameras
b) converging mirrors and lenses
c) diverging mirrors and lenses

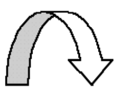
Note: the magnification for converging lenses is always negative because

a) the image is inverted or
b) the image is virtual and d_i is negative

What does a negative sign mean when using the thin lens equation?

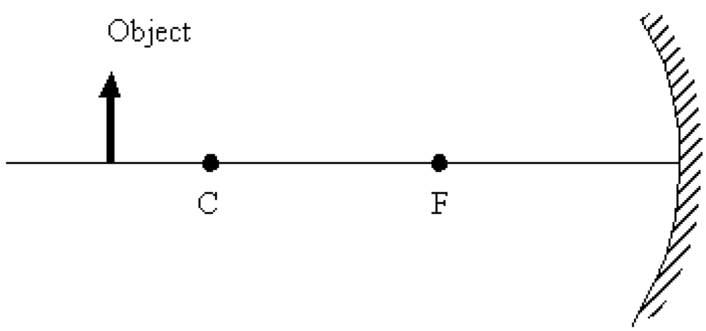
1. If d_i is negative,the image is virtual.

2. If h_o or h_i is negative, the object or image is inverted. Upright is positive, pointing downwards is negative.



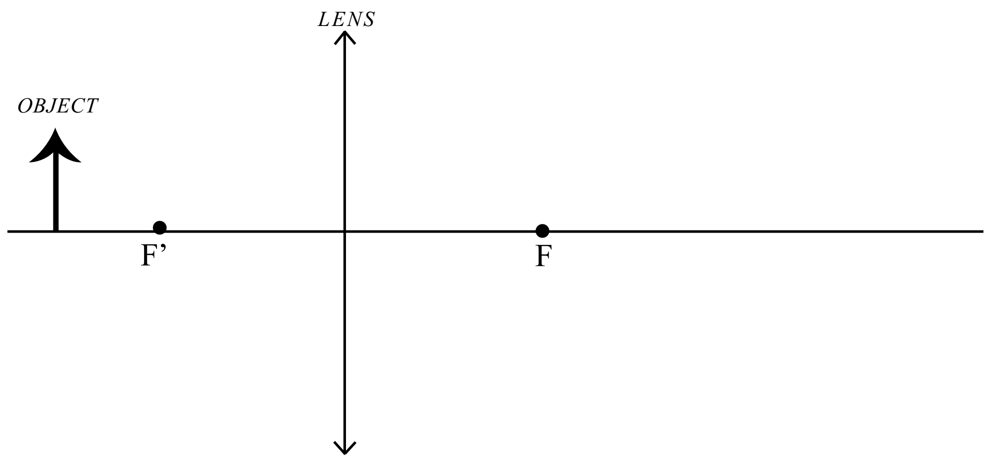
SAMPLE QUESTIONS

1. *Look at the diagram below. A 8 cm tall object is placed in front of a concave mirror. The focal length is 30 cm. The object is located 70 cm from the top of the mirror.*



What will be the height of the image reflected by the mirror?

2. *An object 9.0 cm high is 15 cm from a converging lens having a focal length of 10 cm.*



What is the magnification of the image?

3. *Mary wants to project the image of an object on a vertical screen using a converging lens with a focal length of 60 cm. The image must be 5 times larger than the object.*

   How far from the object must she place the lens?

5. IMAGES **5.9 The Human Eye**

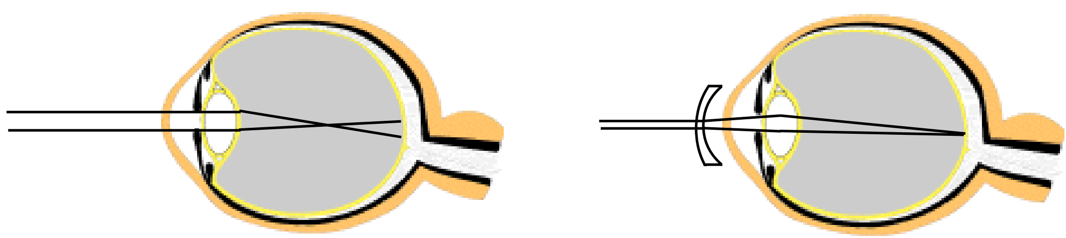
Identify ways of correcting visual abnormalities, using the knowledge of lenses.

§ 5.9 pp. 125-129.

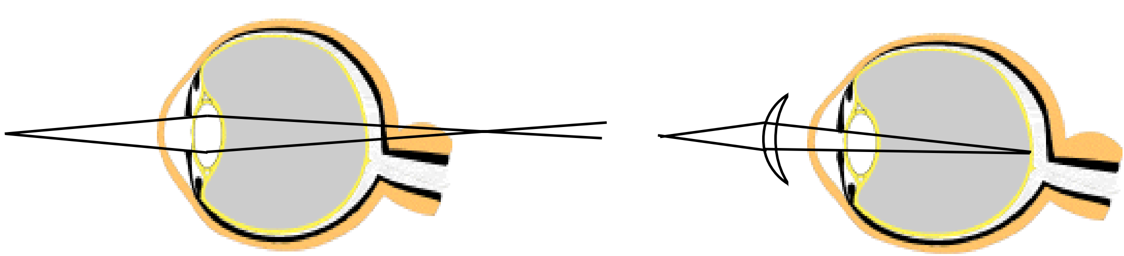
Key Concepts:

Types of Vision Problems:

1. **Myopia (Nearsightedness)**
   Problem - Image of a distant object is focused in front of the retina
   Correction - a diverging lens causes the rays to diverge slightly so they focus on the retina.



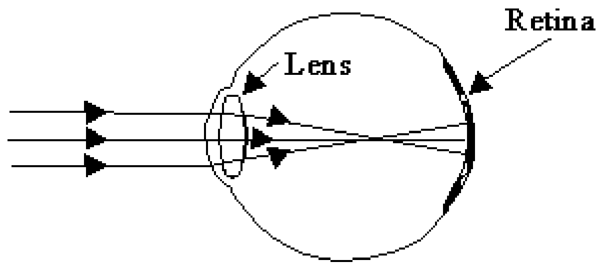
2. **Hyperopia, Presbyopia - (Farsightedness)**
   Problem - image of a close object is focused behind the retina
   Correction - converging lens causes rays to converge on the retina.



Note - If the image focuses in front or behind the retina, the brain perceives the image as blurry.

SAMPLE QUESTION

1. *The following diagram illustrates a visual problem.*



Corrective lenses are used to rectify this problem.

1. *What type of visual problem affects this person?*
2. *Draw the proper lens to correct this person's vision.*
3. *How does the lens affect the path of light within the eye?*

MODULE 3 (MECHANICS)

1. SIMPLE MOTION **1.1 Types of Motion**

Identify various types of motion observed in objects and organisms in their environment and in the laboratory.

§ 7.1: pp. 158-159.

Key Concepts:

1. The branch of physics that deals with describing the motion of objects is known as **kinematics**.

2. The motion of objects and organisms can be categorized under three different types of motion:

    a) **rectilinear**
    b) **curvilinear**
    c) **random**

3. Rectilinear motion can be described as motion along a straight line.

    ie. a ball falling straight down from the roof of a building, a sprinter running in a lane for the 100 meter dash, and a car travelling straight down a street.

4. Curvilinear motion can be described as motion along a curved path.

5. Random motion can be described as motion made up of a combination of both rectilinear and curvilinear motion.

    Ie. a fly in a room, an airplane taking off from a runway and turning left, and a skier leisurely travelling down a slope and carving s-turns.

SAMPLE QUESTION

1. *In the laboratory, Marie-Eve observes the trajectory of different objects moving in different situations.*

    Which trajectories are curvilinear?

    1. *A ball falls to the ground after having rolled across the table.*
    2. *The valve of a moving bicycle wheel*
    3. *A weight oscillating vertically on the end of a spring*
    4. *A slider on an air-track*

    A) 1 and 2 ***B) 2 and 3***

    C) 1 and 4 ***D) 3 and 4***

1. SIMPLE MOTION **1.2 Trajectories**

Illustrate by means of diagrams, the trajectories of moving objects observed in their immediate environment and in the laboratory.

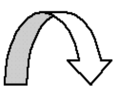
§ 7.2: pp. 159-160.

Key Concepts:

1. **Trajectory** is a term used to describe the path of an object in motion.

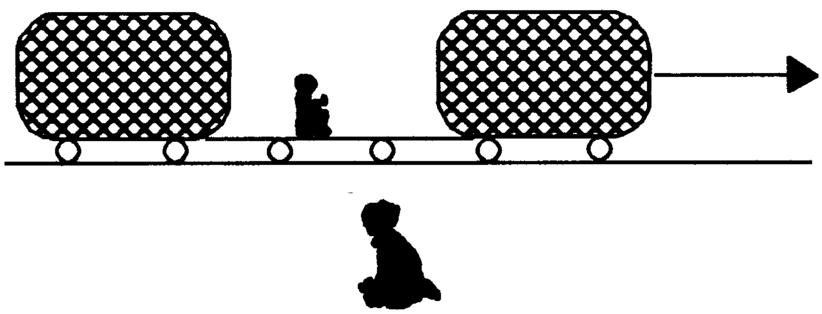
2. **Distance travelled** is a measure of the length of the path of an object in motion.

3. **The total distance** does not always equal the distance between the initial and final points.



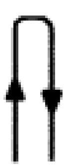
SAMPLE QUESTION

1. *Donald is sitting beside a railway track watching railway cars moving to his right at a constant speed. Suddenly he notices a person on one of the cars in front of him throw a metal bolt directly upward.*



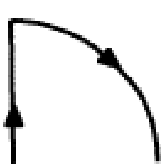
What is the trajectory of the metal bolt that Donald will see? (Disregard air resistance.)

A)



C)

B)



D)

1. SIMPLE MOTION **1.3 Non-visible Motion**

Describe a motion not directly visible to the naked eye after doing a laboratory experiment.

§ 7.3: pp. 160-162.

Key Concepts:

1. Motion of objects or substances can be detected by human senses other than sight.

2. Human senses other than sight can be used to estimate movements “observed.”

   ie. feeling an insect moving on your skin in the dark, hearing the sound of an approaching train, smelling your favourite food baking in another room.

1. SIMPLE MOTION **1.5 Relative Motion and Vantage Point**

Represent the trajectory of a moving object observed from different vantage points, after doing an experiment in the laboratory or the environment.

§ 7.4: pp. 163.

Key Concepts:

1. Depending on the **vantage point**, an object will appear to be traversing a different path of motion.

   Ie. A baseball that is thrown from the outfield to home plate, will appear to be traveling in a different path for the catcher (coming straight at him) who is awaiting to catch the ball, the spectator who is directly behind the fielder who threw the ball, and the manager who is watching this from the dugout on the side of the field.

1. SIMPLE MOTION **1.6 Motion Vectors and Scalars**

Illustrate by means of vectors, the motion of objects.

§ 7.5 to 7.10: pp. 163-170.

Key Concepts:

1. A **scalar** quantity is completely described by its magnitude. The magnitude is made up of a number and an appropriate unit of measurement. Scalar quantities can be added or subtracted arithmetically using ordinary addition or subtraction. Scalar quantities have no direction.

   Ie. 10 grams, 12 liters, 15 miles, 6 centuries, 85 kg.

2. A **vector** quantity is characterized by both magnitude and direction. Force is an example of a vector quantity because force must always act in some direction. A force is described in full only when both its magnitude and direction is given. Other examples of vectors include displacement and velocity. Vector quantities, because they have direction, must be added or subtracted "vectorially."

   Ie. 6 km [N], 20 m/s [S], 500 N [down], 9.81 m/s^2 [up].

3. **Displacement** can be described as drawing a straight line from the object's starting position, and the object's final position. Displacement describes both the magnitude and the direction of a change in position.

   $\vec{\Delta d} = \vec{d}_2 - \vec{d}_1$

   $\vec{d}_1$ is the initial position

   $\vec{d}_2$ is the final position

   $\vec{\Delta d}$ is the displacement

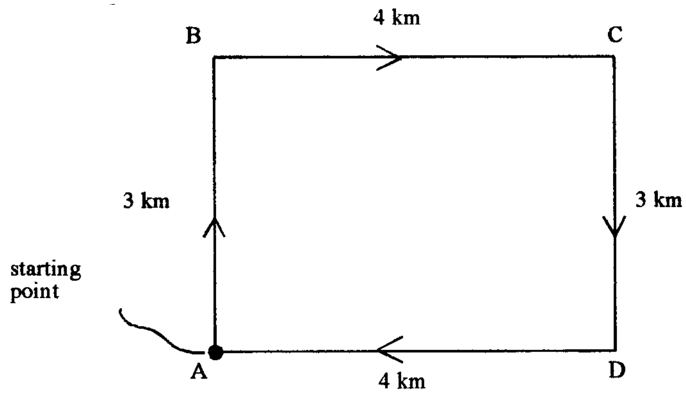
4. **Position** can be described as where an object is located at a specific moment relative to a landmark.

   Ie. Two students are standing at a position 500 m [W] of a building. They begin to walk 1000 m due East. What is their final position relative to the building?

   <u>*Solution:*</u>
   If the students moved due East, then their position relative to the building is about 500 m [E] of the building. Their displacement is 1000 m [E] (relative to their starting point).

SAMPLE QUESTIONS

1. *A hiker covers a course similar to the one represented in the following diagram.*

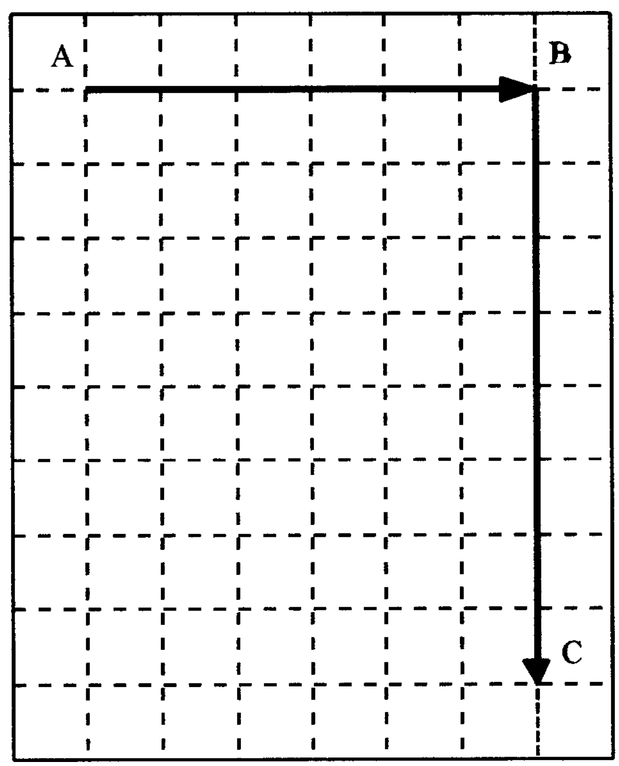


At point C on the course, what is the ratio of the magnitude of the displacement to the distance travelled by the hiker?

2. *A young man moves from point A to point B, a distance of 600 m, then goes from B to C, a distance of 800 m.*

His displacement is shown on the diagram on the right: What is the young man's resultant vector displacement?

The resultant vector displacement is:
magnitude: ___________
direction: ___________



2. FORCES **2.1 Introduction to Forces**

Analyze the effect of forces they have felt or which act on objects in their environment. Describe what they feel when a system of forces acts on them.

§ 8.1: pp. 172-173.

Key Concepts:

1. Simple examples of forces include a push or a pull.

2. Forces allow objects to speed up or slow down, compress or elongate, go up or come down, turn around or travel in a straight line, keep objects stationary or moving, to name a few examples.

2. FORCES **2.2 Effects of Forces**

Recognize the effects of forces which act on objects in their environment.

§ 8.2: pp. 174.

Key Concepts:

1. Physicists believe that there are essentially four basic forces that have an effect on objects in their environment.

2. The **force of gravity** holds large objects such as stars, planets, and moons together and controls their motion. It acts between all objects that have mass.

3. **Electromagnetic force** is the force between moving or stationary electrical charges. It holds atoms and molecules together.

4. **Strong nuclear force** holds the positively charged protons together in the nuclues of an atom even though there is a tendency for the particles to repel each other.

5. The **weak nuclear force** allows elementary particles such as the neutron to break up into other particles.

2. FORCES	**2.3 Adding Force Vectors**

Find the equilibrant force of a system of forces whose effects they have felt or observed, after carrying out an experiment.

§ 8.3: pp. 175-180.

Key Concepts:

1. Numerous forces often act upon objects.

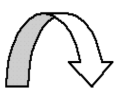
2. Physicists often use a system of force vectors to illustrate how force(s) act upon an object.

3. The resultant force that is the vector addition or sum of the individual forces acting on an object is known as the **net force** or the **unbalanced force** ($\vec{F}_{net}$). The unit of force is the Newton (N).

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots + \vec{F}_n$$

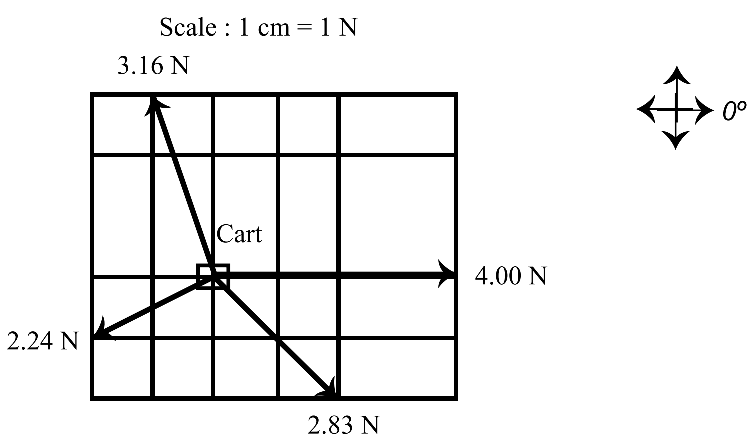
4. Force is a vector quantity therefore it has both magnitude and direction.

5. The **equilibrant force** or **equilibrium force** ($\vec{F}_{eq}$) is the equal and opposite force of the net force or the unbalanced force. It is the force that produces equilibrium. Its magnitude is equal to that of the net force or the unbalanced force, however the direction is opposite to that of the net force or the unbalanced force. In order to determine the equilibrant force, you must first find the resultant force ($\vec{F}_{net}$).



SAMPLE QUESTIONS

1. The following diagram shows 4 forces acting on a cart that is free to move in any direction.

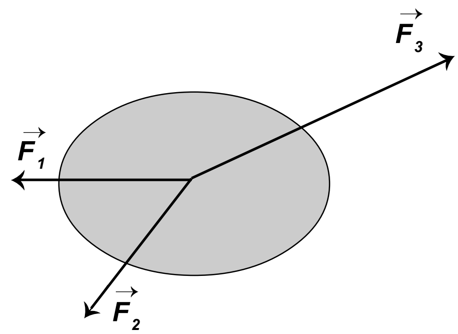


Which one of the following forces will put this system of forces into equilibrium?

A) 3.00 N, 0°   ***C) 3.00 N, 180°***

B) 12.2 N, 0°   ***D) 12.2 N, 180°***

2. *An object is subjected to 3 forces applied to its center of gravity.*



What condition must be met for the object to remain motionless?

A) $\vec{F}_1 + \vec{F}_2 + \vec{F}_3 = 0$

B) $F_1 + F_2 + F_3 = 0$

C) $\vec{F}_1 + \vec{F}_2 = \vec{F}_3$

D) $F_1 + F_2 = F_3$

2. FORCES **2.4 Hooke's Law**

Establish a relationship between the deformation of an elastic substance and the force acting on it.

§ 8.5: pp. 180-183.

Key Concepts:

1. Sir Robert Hooke (1635-1703) stated that the stretching of a spring varies directly with the force acting on the spring.

2. The spring can be stretched up to a maximum point without permanent deformation. Beyond this point, Hooke's law will not apply.

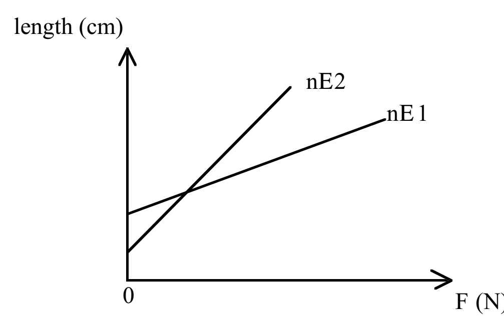
3. The equation for **Hooke's Law** is $F = k\,x$ where:

   F is the force exerted on the deformed spring in newtons (N),
   x is the amount of deformation in meters (m),
   k is the spring constant in newtons per meter (N/m).

SAMPLE QUESTIONS

1. *In the laboratory, the elasticity of two springs was tested. The results are shown in the graph below.*

   Which of the two springs was the easier to stretch?



2. *A mass of 500 g stretches a spring 8.0 cm when it is attached to it.*

   What additional weight would you have to add to it so that the spring is stretched 10 cm?

2. FORCES	**2.8 Vector Problems**

Analyse the effects of force by solving problems, doing numerical exercises and drawing graphs.

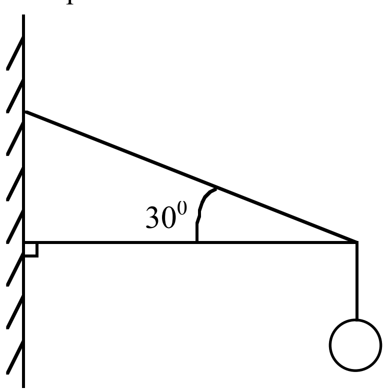
Key Concepts:

1. Draw a free body diagram.

2. Draw a vector diagram. Remember that vectors are added 'tip to tail'.

3. Solve the vector diagram, using either a scale drawing or trigonometrically.

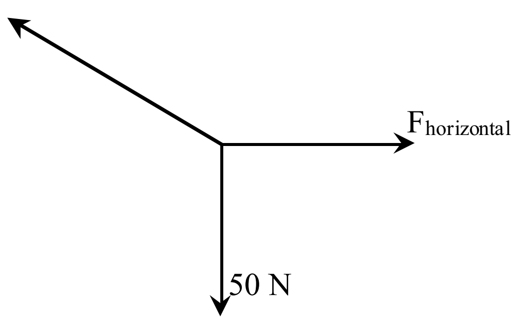
Example:



A lamp weighing 50 N hangs from two metal supports at an angle of 30^0 as shown in the diagram.

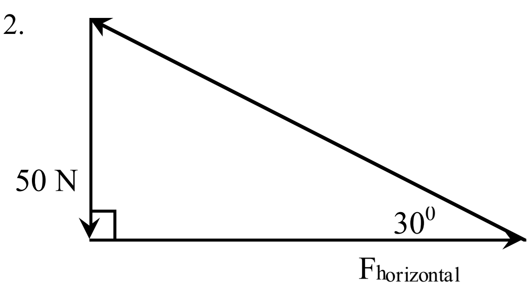
Determine the force acting on the horizontal support.

1.



(free body diagram)

2.



(vector diagram)

3. $\frac{50 \text{ N}}{F_{horizontal}} = \tan 30^0$ $F_{horizontal} = 86.6$ N

Since forces are vectors, your answer must include the direction.

Answer: The force in the horizontal support is 87 N away from the wall.

3. KINEMATICS **3.1 Uniform Motion**

Describe the movement of objects using physical values that can be analyzed during experiments.

§ 9.1: pp. 193-198.

Key Concepts:

1. The simplest type of motion according to physicists is that of an object moving in a straight line, in a specific direction, and at a constant speed.

2. Such motion is referred to as **uniform motion.**

3. **Velocity** of an object is the displacement of the object over a given amount of time. Velocity is a vector quantity. If the velocity is uniform, the formula that describes this motion is:

$$\vec{v} = \frac{\Delta\vec{d}}{\Delta t}$$

$\vec{v}$ is the uniform velocity,

$\Delta\vec{d}$ is the displacement in meters,

Δt is the time interval.

4. **Speed** is the scalar that is defined as the total distance traveled in a unit of time.

$$\textbf{Speed} = \frac{distance}{time} \quad \textbf{or} \quad v = \frac{\Delta d}{\Delta t}$$

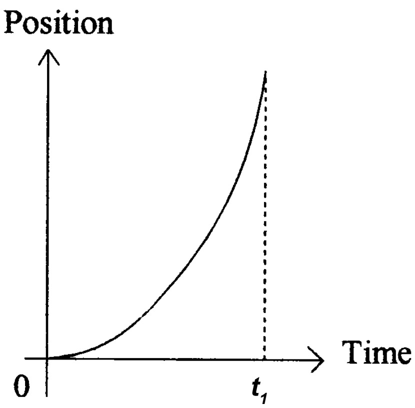
where: v is the speed,
Δd is the distance traveled,
Δt is the time interval.

Refer to § p. 195, Sample Problem for an example which illustrates the calculations for distance, speed, displacement and velocity.

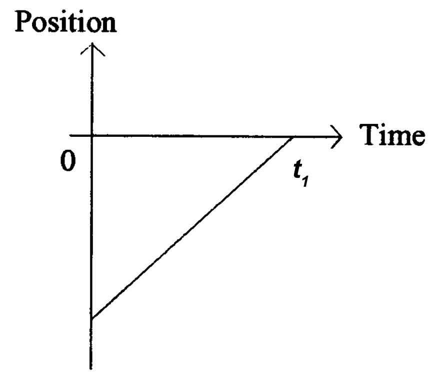
SAMPLE QUESTION

1. *Which one of the following position-time graphs shows a moving object slowing down uniformly between times 0 and t_1?*

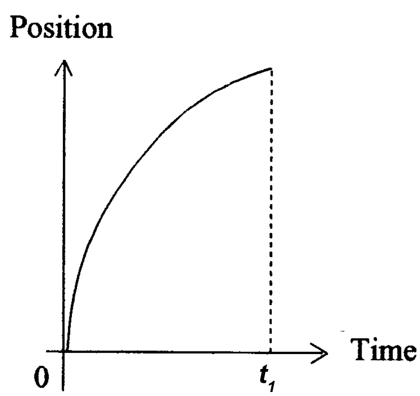
A)



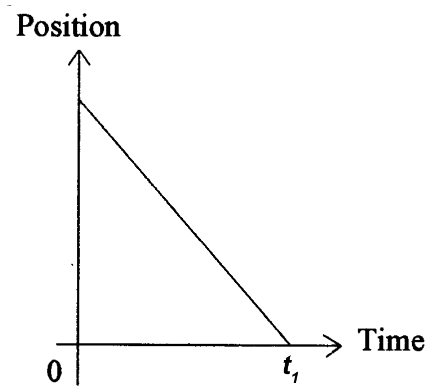
C)



B)



D)



3. KINEMATICS **3.2 Graphing Motion**

Describe the motion of objects by plotting a position-time graph.

§ 9.2: pp. 198-201.

Key Concepts:

1. A body moving at a constant speed travels the same distance during each second of motion. The total distance traveled varies directly with the time elapsed.

2. A graph of position as a function of time is a straight line for this motion at constant speed.

3. Taking the **slope** of a position-time graph for a given interval of time will equal speed.

3. KINEMATICS **3.2 Graphing Motion**

Describe the motion of objects by plotting a position-time graph, and describing the motion at different time intervals or points.

§ 9.3: pp. 201-208.

Key Concepts:

1. Generally, objects speed up, slow down, and change directions. As a result, these objects cannot always follow the concept of uniform motion for a long period of time.

2. Plotting a displacement-time graph allows you to determine the actual position of an object with respect to a starting point, at any given point in time.

3. The **slope** of the graph between two points is the velocity of the object during that given time interval. If the slope is positive, then the object is said to be traveling away from its starting or reference point. If the slope is negative, then the object is said to be traveling towards its starting or reference point. A slope of zero (0) implies the object is at rest.

4. **Average velocity** for an object that changes its velocity frequently, is calculated by taking the total displacement of the object from the start to the finish divided by the specific time interval.

$$\textbf{Average velocity} = \frac{\textit{total displacement}}{\textit{time interval}}$$

$$\vec{v}_{av} = \frac{\Delta\vec{d}}{\Delta t}$$

5. **Average speed** for an object that changes its speed frequently, is calculated by taking the total distance covered by the object from the start to the finish divided by the specific time interval.

$$\textbf{Average speed} = \frac{\textit{total distance}}{\textit{time interval}}$$

$$v_{av} = \frac{\Delta d_{total}}{\Delta t}$$

6. The **instantaneous velocity** of an object at a certain point in time is calculated by taking the slope of the tangent to the curve (displacement-time) at that given point in time.

SAMPLE QUESTION

1. *A parachutist whose mass is 100 kg opens his parachute at a height of 1000 m. The parachute exerts a retarding force (air resistance) of 980 N. The descent is vertical and lasts 5.0 min.*

   At what velocity is the parachutist travelling on landing?

   A) 3.3 m/s ***B) 6.6 m/s***

   C) 49 m/s ***D) 140 m/s***

3. KINEMATICS **3.3 Non-Uniform Motion**

Analyze the acceleration of an object in non-uniform motion.

§ 9.4: pp. 208-218.

Key Concepts:

1. **Acceleration** is the rate at which velocity is changing with time. If the velocity is increasing, the acceleration is positive. If the velocity is decreasing, the acceleration or deceleration is negative.

$$a = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t} \quad or \quad \frac{\Delta\vec{v}}{\Delta t}$$

where: $\vec{a}$ is the acceleration in m/s^2,

$\vec{v}_2$ is the final velocity in m/s,

$\vec{v}_1$ is the initial velocity,

Δt is the interval of time in s.

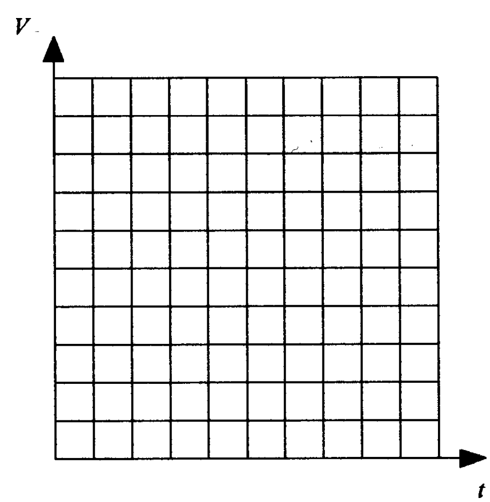
2. The **slope** of a velocity-time graph is equal to the acceleration of the object. If the slope is positive, then the object is said to be accelerating (increasing its velocity). If the slope is negative, then the object is said to be decelerating (slowing down). A slope of zero (0) implies the object is moving at a constant (uniform velocity).

3. Displacement can be calculated from the velocity-time graph. The **area** between the horizontal axis of a velocity-time graph and the curve is equal to the displacement of the object for a given time interval.

SAMPLE QUESTION

1. *An automobile is being driven at a constant velocity on a straight road. The car slows down when it comes to a village, comes to a stop at an intersection, then sets off again and a ccelerates at a constant rate leaving the village.*

   Show what has occurred by constructing the velocity-time graph for the automobile.



3. KINEMATICS	**3.5 & 3.6 Equations of Uniform Acceleration and Free Fall**

Analyze the motion of an object in uniform acceleration and free fall utilizing the equations of uniform acceleration.

§ 9.5: pp. 218-226.

Key Concepts:

1. If acceleration is constant, acceleration is the slope of a velocity vs. time graph.

2. The area between the curve and the axis of a velocity vs. time graph is equal to the displacement from $\vec{v}_1$ to $\vec{v}_2$ and time interval t_1 to t_2.

3. The equations that are used to solve problems with uniform acceleration only are as follows:

$$\vec{v}_2 = \vec{v}_1 + \vec{a}\Delta t$$

$$\Delta\vec{d} = \vec{v}_1\Delta t + \frac{1}{2}\vec{a}(\Delta t)^2$$

$$\Delta\vec{d} = \left(\frac{\vec{v}_1 + \vec{v}_2}{2}\right)\Delta t$$

$$(\vec{v}_2)^2 = (\vec{v}_1)^2 + 2\vec{a}\Delta\vec{d}$$

where: $\vec{a}$ is the acceleration in m/s^2,
$\vec{v}_2$ is the final velocity in m/s,
$\vec{v}_1$ is the initial velocity,
Δt is the interval of time in s,
$\Delta\vec{d}$ is the displacement in m.

4. When the motion is along a straight line, vector notation can be omitted for the equations above, but you must be careful to respect the signs (positive and negative) of the variables.

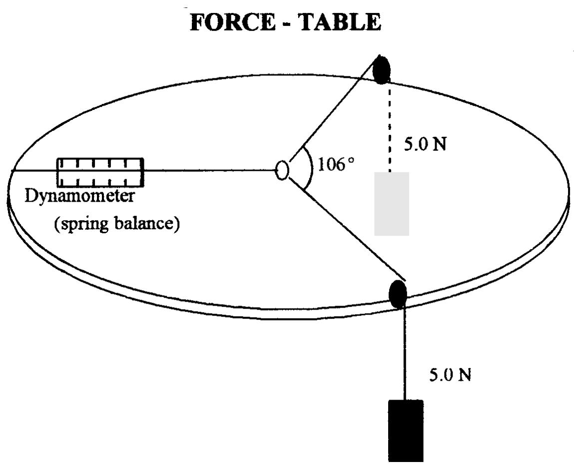
5. Near the surface of the earth, the acceleration due to gravity (a_g) is 9.8 m/s^2. The direction is downwards, toward the surface of the earth, even if the motion of an object is up, away from the surface of the earth.

6. In order to solve problems involving free fall, one can use 9.8 m/s^2 [down] as the acceleration due to gravity (a_g or g).

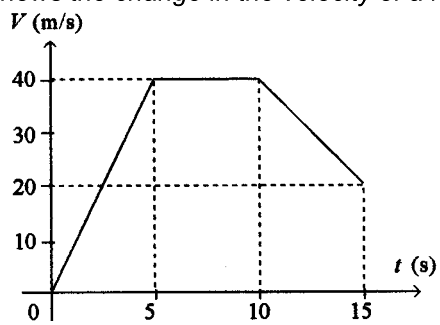
SAMPLE QUESTIONS

1. *On a force-table, two objects weighing 5.0 N each are held in position as shown in the diagram below.*

   Calculate the force that is shown on the dynamometer (spring balance).



2. *The following graph shows the change in the velocity of a race car, moving in a straight line path, as a function of time.*



   What distance does this car travel during the first 15 seconds?

   A) 60 m ***B) 450 m***

   C) 550 m ***D) 700 m***

3. *A remote-control vehicle travels in a straight line on a plane surface. The remote-controller varies the speed.*

   Below is a table of instantaneous speeds measured every two seconds.

Time (s)	*Speed (m/s)*
0	*0.6*
2	*1.5*
4	*1.8*
6	*1.2*
8	*1.6*
10	*0.8*

   Calculate the approximate distance travelled during the ten seconds.

3. KINEMATICS 3.9 Problem Solving (mathematical and graphical) of Motion

Analyze the motion of an object in uniform and non-uniform motion to solve problems mathematically and/or graphically.

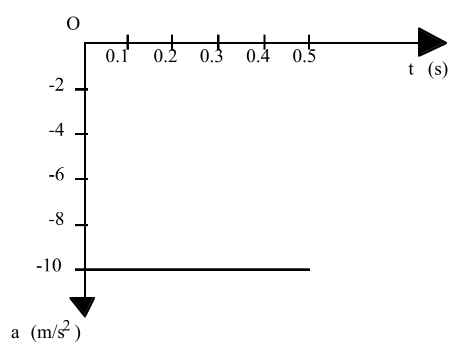
§ 9.10: pp. 239-248.

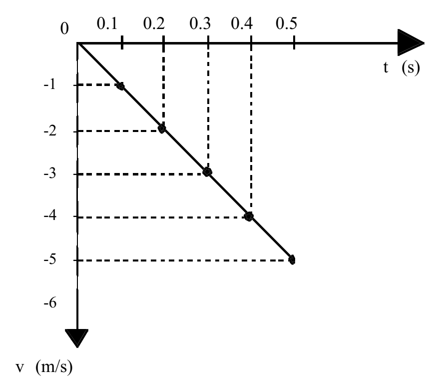
Key Concept:

1. In order for a student to solve problems of uniform and/or non-uniform motion, he/she should:
   i. Read each problem carefully, identifying all the known data.
   ii. Use the correct mathematical equation after analyzing what is asked for in the problem and solve the problem using that equation.
   iii. Verify that the units and magnitude of the answer are consistent with what is given and what is asked for in the problem.

SAMPLE QUESTIONS

1. *During an experiment, Joanna and Vanessa drop a ball vertically downwards. The graphs show the results of their experiment.*





If the ball hits the ground 0.5 s after it was dropped, from what height did it fall?

2. *A marble, initially at rest, is allowed to roll down an inclined plane. During its descent, it accelerates uniformly and travels 10 cm during the first second (1.0 s).*

   At this rate, what distance will the marble have travelled after 5.0 seconds?

3. *An object is thrown vertically upwards at time* $t = 0$. *It falls back to the same spot at time* $t = t_f$

   Draw the graphs associated with the motion of this object : *1) velocity-time*
   2) position-time

4. DYNAMICS   **4.1 Causes of Changes in Motion (Law of Inertia)** **Identify, after making observations, the cause of changes in the state of rest or state of motion of an object.** § 10.1 to 10.3: pp. 249-256.

Key Concepts:

1. **Inertia** is the tendency for a body to resist a change in its motion.

2. **Newton's first law of motion** states that a body continues in its state of rest, or of uniform motion in a straight line, unless it is acted upon by a net external force.

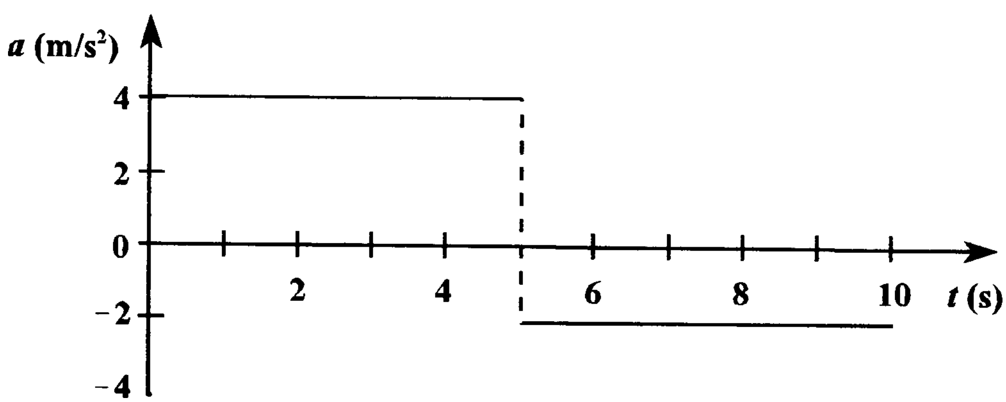
3. This law states that it is the natural tendency of a body to maintain its motion or state of rest.

4. A body will resist any change in its state of motion. As a result, a force is only capable of changing the state of motion of a body.

5. Inertia is directly related to the mass of an object.

SAMPLE QUESTION

1. The following graph illustrates the data gathered during an experiment on the motion of a cart.



According to this graph, what is the change in the velocity of the cart during the first 5 seconds of its motion?

A) 0 m/s   ***B) 4 m/s***

C) 10 m/s   ***D) 20 m/s***

4. DYNAMICS **4.2 & 4.3 Effect of Force and Mass on Acceleration Newton's Law of Acceleration**

Measure the acceleration of objects of different mass to which force is applied, and link the various factors that affect the acceleration of an object (Law of Acceleration).

§ 10.4: pp. 257-263.

Key Concepts:

1. Newton was the first to recognize that a net force always causes acceleration and not just motion.

2. When an unbalanced force acts on a body, the body will be accelerated.

3. The acceleration will vary directly with the applied force and will be in the same direction as the applied force.

4. The acceleration will vary inversely with the mass of the body.

5. The mathematical expression of Newton's second law is:

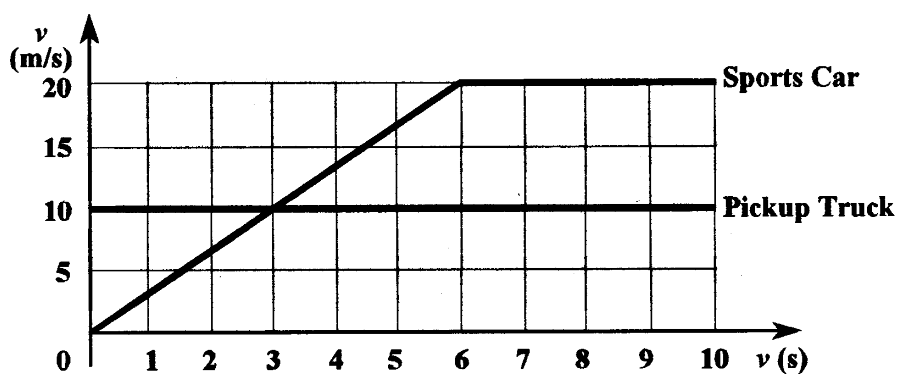
$$\vec{F}_{net} = m\vec{a}$$

where: $\vec{F}_{net}$ is the net force in newtons (N),
m is the mass in kg,
a is the acceleration of the object in m/s^2.

SAMPLE QUESTIONS

1. *A sports car is waiting for a red light to change. When the light turns green, a pickup truck travelling at a constant velocity passes the sports car as it starts to move.*

   The following graph represents the velocities of the two vehicles as a function of time.



At what time, t, *will the sports car pass the pickup truck?*

2. *In automobile racing, there is a constant effort to increase the performance of the cars, particularly the acceleration. An engineer proposes the four following suggestions. Which one of these would, in fact, REDUCE acceleration?*

   A) Increase the propulsion force of the motor.

   B) Increase the weight of the car.

   C) Decrease the mass of the car.

   D) Reduce the friction forces.

4. DYNAMICS **4.4 Weight**

Appreciate that bodies fall because of weight and distinguish between mass and weight.

§ 10.5: pp. 263-267.

Key Concepts:

1. **Newton's second law** can be adapted to express the weight of an object.

$$F_g = mg$$

where: F_g is the force of gravity on an object in N,
m is the mass of the object,
g is the gravitational field strength in N/kg.

2. **Mass** depends on the amount of matter in a body. It is related to the actual number of protons, neutrons, and electrons that make up a body.

3. **Weight** refers to the gravitational force exerted on a body by the earth. Weight is another name for the force exerted by the earth's gravity on an object of mass, m. It is measured in newtons (N).

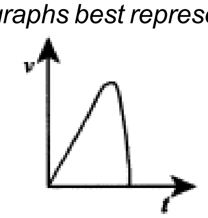
4. The mass of an object is the same no matter where it is. The weight depends on the gravitational field strength (e.g. an object will weigh more near the Equator than near the poles).

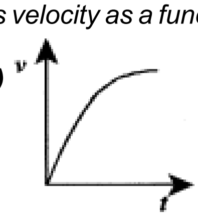
5. The moon's gravitational field strength is weaker than the earth's. Objects weigh less on the moon than on earth.

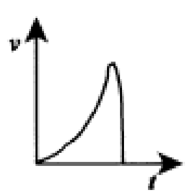
SAMPLE QUESTION

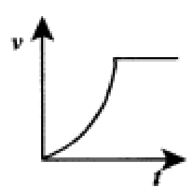
1. While making a movie, a stunt man falls from the roof of a house onto a thick mat at ground level. The mat cushions his fall and he does not bounce.

Which of the following graphs best represents the stunt man's velocity as a function of time during his fall?

A)


B)


C)


D)


4. DYNAMICS **4.6 Frictional Forces**

Identify factors that influence the magnitude of frictional forces.

§ 10.8: pp. 277-281.

Key Concepts:

1. **Static friction** (starting friction) is the force that keeps an object stationary or from sliding.

2. **Kinetic friction** (sliding friction) is the force that opposes an object that is already in motion.

3. Other frictional forces include rolling friction and frictional resistance due to fluids such as air and or water.

4. Variables that affect friction include mass and roughness of surface. Other variables that do not affect friction include speed and surface area.

SAMPLE QUESTION

1. Julie was driving a 1200-kg car at 90 km/h. She suddenly applied the brakes and the car stopped. The total braking force was 2400 N.

What was the stopping distance of this car?

A) 6.25 m ***B) 12.5 m***

C) 156 m ***D) 313 m***

5. SIMPLE MACHINES, WORK & POWER **5.1 Simple Machines and Work**

Identify simple machines and systems composed of simple machines in the environment.

§ 11.1: pp. 288-289.

Key Concepts:

1. A **simple machine** is a single mechanical device used to perform work more efficiently by providing a mechanical advantage.

2. The **mechanical advantage** of a machine is the multiplier of the force or the speed. It is a number that allows us to know how many times a machine multiplies a force or speed.

3. The **ideal mechanical advantage (IMA)** is the ideal advantage for an ideal machine. It is the maximum mechanical advantage that a frictionless machine can deliver.

4. The **actual mechanical advantage (AMA)** is the ideal advantage for an ideal machine minus its loss of energy due to heat and sound as a result of friction. It is less than the IMA.

5. A machine requires energy to operate. Since energy is neither created nor destroyed, it is impossible for any machine to put out more energy than needed by the machine.

6. Simple machines include levers and inclined planes. Levers are subdivided into levers, wheel and axles, and pulleys. Inclined planes include the inclined planes, the wedge, and the jack screw.

7. **Efficiency** tells us what percentage of the input energy is lost due to friction. Since the ideal machine has no energy loss because there is no friction, its efficiency is 100%. The real machine has energy loss because there is friction, resulting in efficiency that is <100%.

$$\text{Efficiency} = \frac{\text{A.M.A.}}{\text{I.M.A.}} \times 100$$

8. The following notations are utilized when describing the terms of simple machines;

$\boldsymbol{F_E}$ is the effort force that is applied,

$\boldsymbol{F_R}$ is the resistance force that opposes the F_E

$\Delta \boldsymbol{d_E}$ is the effort distance through which the effort force acts,

$\Delta \boldsymbol{d_R}$ is the resistance distance through which the resistance force acts.

5. SIMPLE MACHINES, WORK & POWER **5.2 & 5.3 Work & Efficiency**

Describe the work performed by a simple machine in moving an object, using effort, effort distance, resistance, and resistance distance. Justify the selection of a simple machine to do a particular type of work.

§ 11.2: pp. 289-298.

Key Concepts:

1. Recall that **work** is done on an object when a force makes that object move.

2. The unit of measure for work is commonly known as the Joule (J). The formula that measures the amount of work done is:

$$W = \vec{F} \bullet \Delta\vec{d}$$

where: $\vec{F}$ is the applied force in newtons (N)

$\Delta\vec{d}$ is the displacement of the object in meters (m)

W is work done in joules (J).

3. By definition, work is a transfer of energy caused by a force acting through a distance. If force acts parallel to the direction of the displacement, then $W = F\Delta d$.

4. When the force is not parallel to this direction, $W = (F \cos \theta)\, \Delta d$, where θ is the angle between the applied force and the parallel component of the applied force.

5. For simple machines, work is an important component in that simple machines often move objects along a certain distance. The two formulas that relate work to simple machines are as follows:

$$\text{work input} = \text{effort force} \times \text{effort distance} = F_E\ \Delta d_E$$

$$\text{work output} = \text{resistance force} \times \text{resistance distance} = F_R\ \Delta d_R$$

6. The efficiency of a Simple machine can be calculated as follows:

$$\text{Efficiency} = \frac{\text{work output}}{\text{work input}} \times 100\%$$

$$= \frac{F_R \Delta d_R}{F_E \Delta d_E} \times 100\%$$

7. For levers, the following formulas apply:

$$\frac{\Delta d_E}{\Delta d_R} = \frac{F_R}{F_E} \qquad \text{(100\% efficient)}$$

$$\text{I.M.A.} = \frac{\Delta d_E}{\Delta d_R} \qquad\qquad \text{A.M.A.} = \frac{F_R}{F_E}$$

8. For a wheel and axle, the following formulas apply:

$$\text{I.M.A.} = \frac{\textit{radius of wheel}}{\textit{radius of axle}} \qquad\qquad \text{A.M.A.} = \frac{F_R}{F_E}$$

9. For the pulley system the following formulas apply:

$$\text{I.M.A.} = \text{Number of supporting ropes} \qquad\qquad \text{A.M.A.} = \frac{F_R}{F_E}$$

where the number of supporting ropes is the number of ropes that are pointing upwards (force is acting up) (See text pp. 289-290).

10. For an inclined plane the following formulas apply:

$$\text{I.M.A.} = \frac{\textit{Length}}{\textit{Height}} = \frac{\Delta d_E}{\Delta d_R} \qquad\qquad \text{A.M.A.} = \frac{F_R}{F_E}$$

SAMPLE QUESTIONS

1. Which of the situations shown below represent mechanical work?

I. A balloon is kept immobile by four wires attached to the ground.
II. A person climbs a staircase carrying a box in his/her hands.
III. A wagon comes tearing down a Russian mountain slope.
IV. Columns are supporting the roof of a building.
V. An arrow is on the bowstring of a drawn bow.

2. What does the expression below enable us to learn about this simple machine?

$$\frac{\textit{Energy supplied by the machine}}{\textit{Energy used by the machine}} \times 100$$

A) The mechanical advantage of the machine

B) The work done by the machine

C) The power of the machine

D) The efficiency of the machine

5. SIMPLE MACHINES, WORK & POWER **5.4 Mechanical Power**

Describe the concept of power and how it relates to work.

§ 11.3: pp. 298-300.

Key Concepts:

1. **Power** is the rate at which work is done.

2. A machine that can accomplish a certain amount of work faster has more power.

3. Power is defined as:

$$P = \frac{W}{\Delta t}$$

where: P is the power measured in watts (W),
W is the work done in J,
Δt is the time interval in s.

SAMPLE QUESTION

1. *Four different machines performed the following tasks :*

Machine 1 : took 2 minutes to lift a mass of 1000 kg to a height of 10 m.
Machine 2 : took 10 minutes to lift a mass of 1000 kg to a height of 10 m.
Machine 3 : took 2 minutes to lift a mass of 500 kg to a height of 10 m.
Machine 4 : took 10 minutes to lift a mass of 500 kg to a height of 10 m.

Which of these machines is the most powerful?

A) Machine 1 ***B) Machine 2***

C) Machine 3 ***D) Machine 4***

6. MECHANICAL ENERGY **6.1 Potential Gravitational Energy**

Relate mechanical work to the potential gravitational energy acquired by an object.

§ 12.1 & 12.2: pp. 304-311.

Key Concepts:

1. The **Law of Conservation of Energy** states that energy can neither be created nor destroyed. It can only be transformed.

2. **Potential Gravitational Energy (E_g)** is stored energy to be used at a future time.

3. When an object is raised, work is done in order to move this object upward and overcome gravity.

4. The energy that is used to raise this object is converted into potential gravitational energy. The formula for this potential gravitational energy is:

$$E_g = mgh$$

where: E_g is the potential energy in J,
m is the mass of the object in kg,
g is the acceleration due to gravity (9.8 m/s^2),
h is the height the object is raised in m.

5. The potential energy of an object does not depend on the path of the object but rather the change in height. The height is perpendicular to the horizontal from where the object was raised.

SAMPLE QUESTION

1. Energy can be present in several different forms in nature.

What is the name given to the form of energy linked exclusively to the position of an object?

A) Kinetic energy ***B) Potential energy***

C) Mechanical energy ***D) Electrical energy***

6. MECHANICAL ENERGY **6.2 Kinetic Energy**

Relate mechanical work to the kinetic energy acquired by an object.

§ 12.3: pp. 311-314.

Key Concepts:

1. **Kinetic Energy** is the energy of motion. The faster an object is moving, the greater the kinetic energy. The energy required to increase the speed or velocity of an object (work carried out on the object) is transferred to the object as kinetic energy.

2. The following formula expresses kinetic energy:

$$E_K = \frac{1}{2}mv^2$$

where: E_K is the kinetic energy in J,
m is the mass of the object in kg,
v is the speed of the object in m/s.

3. The speed of the object at any given time can be calculated from the kinetic energy at that time.

4. To find the work done (energy used) to accelerate an object, you can find the change in the object's kinetic energy.

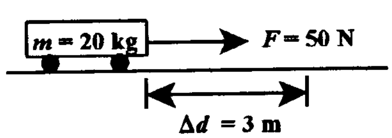
$$\Delta E_K = E_{K\,(final)} - E_{K\,(initial)}$$

$$\Delta E_K = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

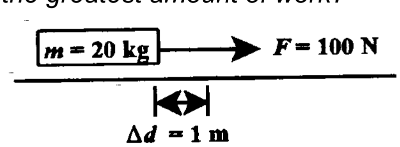
SAMPLE QUESTIONS

1. *In which of the following situations does the applied force,* F*, do the greatest amount of work?*

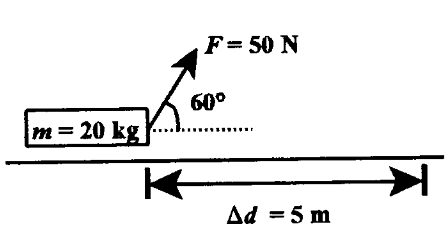
A)



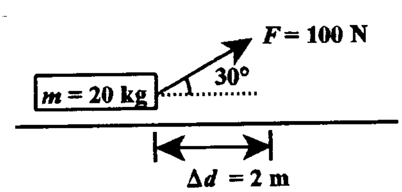
B)



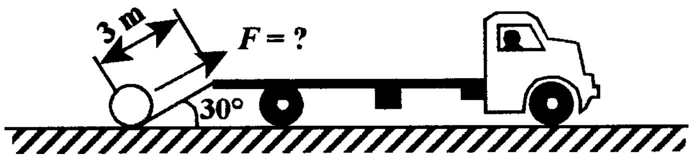
C)



D)



2. *A 200-kg oil barrel is moved up a ramp onto a flatbed truck at a constant speed. The ramp is 3 m long and makes an angle of 30° with the ground. Frictional forces are negligible.*



What is the magnitude of the force that must be exerted parallel to the ramp?

A) 980 N

B) 1697 N

C) 1960 N

D) 2940 N

6. MECHANICAL ENERGY **6.4 & 6.5 Transformation of Mechanical Energy Conservation of Energy**

Analyze the transformation of mechanical energy and the conservation of energy.

§ 12.5 & 12.6: pp. 316-324.

Key Concepts:

1. The **Law of Conservation of Energy** states that energy cannot be created or destroyed. When an object is raised, work is done and the object stores that work in the form of potential gravitational energy.

2. When the object falls freely, the potential energy is converted into kinetic energy. As the object continues to fall, its loss in potential energy becomes a gain in kinetic energy.

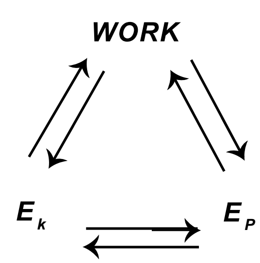
3. At any given point during the fall, the total mechanical energy is the sum of the potential energy and the kinetic energy. At its maximum height, the potential energy will equal the total energy (because there is no kinetic energy if an object is at rest). The instant prior to when an object strikes the ground, the kinetic energy will equal the total energy (because the object is at ground level). All its potential energy (from being situated at a height) was transferred to kinetic energy, assuming no energy loss to friction.

$$E_T = E_k + E_g$$

where: E_T is the total energy in J,

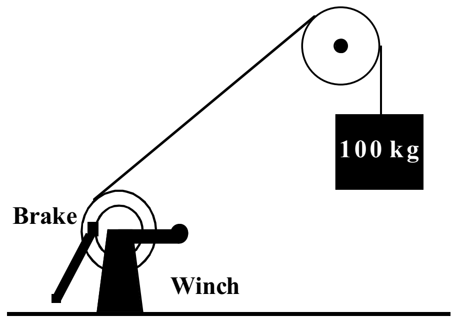
E_k is the kinetic energy in J,

E_g is the potential energy in J .



SAMPLE QUESTION

1. *An object has a mass of 100 kg. Using a winch, you hoist the object 4.0 m off the ground.*



After hoisting the object, you apply the brake. Since this brake exerts a force of only 780 N, the brake slips and the object drops, hitting the ground at a speed of 4.0 m/s. Due to the frictional force of the brake, the stored gravitational potential energy is expended in the form of kinetic energy and thermal energy.

How much thermal energy is dissipated by the brake?

A) 200 J ***B) 800 J***

C) 3120 J ***D) 3920 J***

Examination

554-570 **PHYSICS 534** **JUNE**

Psst ...

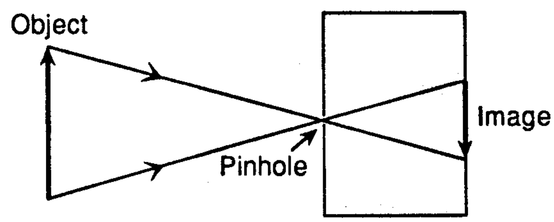
You want the answers to the June exam?
(OK, so it's not this year's exam, but...)

TIME: 3 hours

Part A - Multiple Choice

Question 1 — *SMILE FOR THE CAMERA*

Consider the following diagram:



Which behaviour of light can explain the phenomenon illustrated above?

A) Light forms angles of incidence and angles of reflection that are equal.
B) Light travels in a straight line.
C) The direction of light is changed when it passes through a small opening.
D) Light produces a virtual image.

		BECAUSE ...
CHOOSE...	**B**	The "pinhole camera" is a light-proof box with a pinhole, and a screen at the other end. Light from an object enters the box through the pinhole, and an inverted real image appears on the screen. For the image to be formed, light must travel from the object through the hole to the back of the pinhole camera. Since the ray from the tip of the object continues in its path and reaches the tip of the image, it must travel in a straight line. This is proven again by the ray from the bottom of the arrow. The proper term for this is the rectilinear propagation of light.
NOT...	**A**	This answer makes a correct statement about light but this applies to light reflecting off of a surface and is not the reason for the pinhole camera's operation.
	C	Light does **not** change direction as it passes through a small opening. This statement is not a correct statement and should not be chosen. It may be referring to what happens to light when it passes through a very small opening. Diffraction may occur. This is a form of spreading out of light not creating an inverted image.
	D	This statement does not apply since the image that is formed is in fact a **real** image. It is actually seen on the back of the pinhole camera. I also find the statement too vague. To say that 'light' forms an image does not include the necessity for the light to focus.

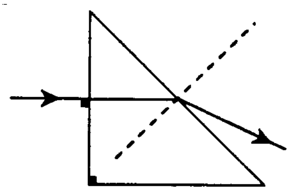
Main Topic: - rectilinear propagation of light, process of image formation
Related Topics: - ratio of image to object equation, shadow formation

Question 2 — *LIGHT AND THE SINGLE PRISM*

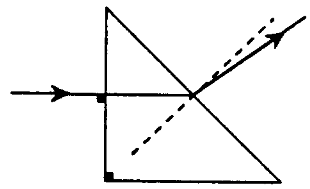
A monochromatic light ray enters a transparent prism from air.

Which of the following diagrams correctly illustrates the path of the light ray?

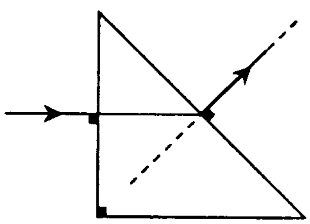
A)



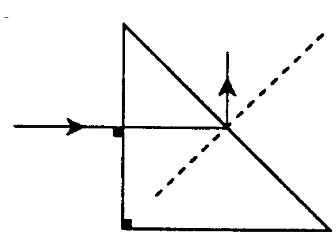
C)



B)



D)



		BECAUSE ...
CHOOSE...	**A**	This question involves the use of Snell's universal equation, $n_1\sin\theta_1 = n_2\sin\theta_2$ When light is incident upon the interface between two optical media at 0°,there is **no** bending (refracting) of the light. The ray continues in a straight line within the medium. When the ray encounters the second interface, the angle of incidence will not be 0° and, therefore, the ray will bend. Since the prism's optical density is greater than that of air, the ray will refract **away** from the normal as it exits. The speeding up of the light causes this bending.
NOT...	**B**	As explained above plus a refracted ray will travel along the normal only if the incident ray is also on the normal. Since this is not the case, the refracted angle cannot return to 0°.
	C	As explained already, the angle must **increase** not decrease (bend towards the normal).
	D	For those who don't realize that refraction is taking place, they might select this answer which seems to show the ray **reflecting** off of the normal (which cannot happen)

Main Topic: - refraction between two different media

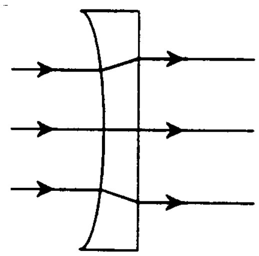
Related Topics: - Snell's law, optical densities, prisms, triangles, and other shapes relating to the direction of refraction

Question 3 — *ALL SHAPES OF LENSES*

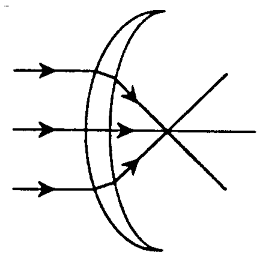
Beams of light rays are travelling through air parallel to the principal axis of four different lenses. The light rays enter the lenses and are refracted.

In which diagram is the path of the light rays correctly illustrated?

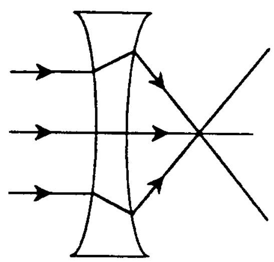
A)



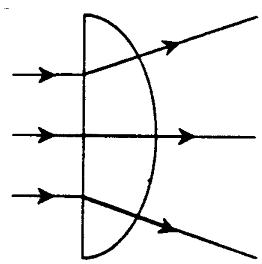
C)



B)



D)



		BECAUSE ...
CHOOSE...	**C**	As light passes through a prism or other shaped optical medium, the light refracts twice. The net result of this double refraction is to bend the ray towards the wider (thicker) part of the shape. This lens is thicker in the middle than it is on the ends, thus refracting the rays towards the principal axis. This shape is more convex than it is concave. This creates a convergent result.
NOT...	**A**	Based on the shape at the ends, the rays should diverge when they emerge. The second refraction should be **away** from the normal.
	B	This shape is definitely a double concave shape. This type of lens is a divergent lens. The rays do not illustrate this. Since the ends are thicker, the rays should diverge from the principal axis.
	D	The first thing that is incorrect about D is that all three rays should continue in a straight line as they enter the lens, not just the center ray.. This is true because they strike the interface at 0°, which will not cause any refraction. The second refraction of the rays is incorrect since the rays are not incident at 90°. Nor do they come from the center of the semi-circle, which might lead you to think that they emerge straight.

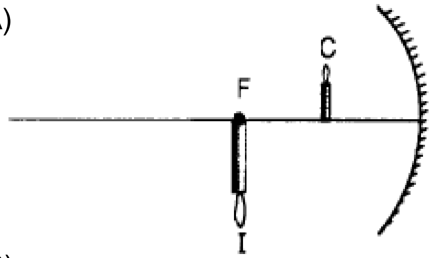
Main Topic: - refraction, shape of lenses, diverging/converging shapes
Related Topics: - type of lenses, corrective lenses

Question 4 *CANDLE, CANDLE BURNING BRIGHT*

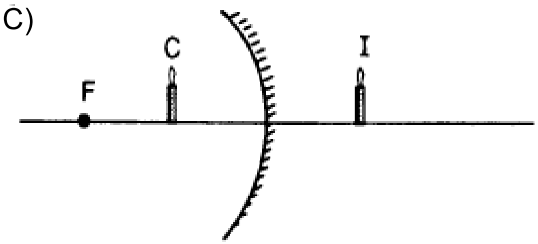
A candle C is placed in front of a concave spherical mirror that has a focal point at F.

Which of the diagrams correctly shows the image **I** of the candle?

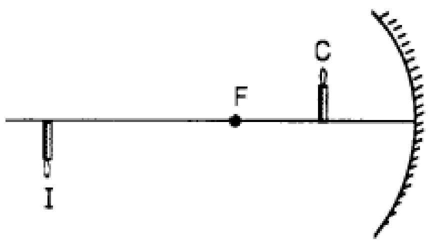
A)



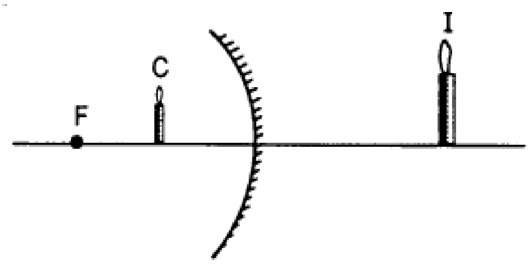
C)



B)



D)



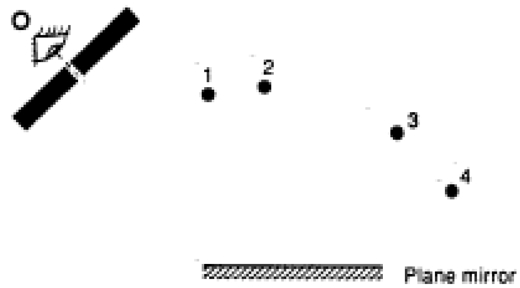
		BECAUSE ...
CHOOSE...	**D**	When an object is placed between the focal point and a concave mirror, a virtual image is created. This image is formed **behind** the mirror. By using a proper ray diagram, it can be shown that the rays **appear** to intersect behind the mirror and that they create an image larger than the object.
NOT...	**A**	Images are not formed at the focal point. Parallel rays are reflected through there, but the formation of an image at this point could only be that of a very distant light source (the sun)
	B	There is no real good explanation for this one. The only position for an object so that the image will be the same size but inverted, is when the objected is placed at the center of curvature. This is not the case for this answer.
	C	The trap in this answer is that the image is correct **only if** the mirror is flat.

Main Topic: - Image formation in curved mirrors
Related Topics: - Ray diagrams for mirrors, plane mirror images

Question 5 — *EYE SEE!*

Light-emitting objects 1, 2, 3 and 4 are placed in front of a plane mirror.

An observer **O**, looking through a small opening, sees the image of only one of these objects.



The image of which object can be seen by the observer?

A) 1

B) 2

C) 3

D) 4

		BECAUSE ...
CHOOSE...	**C**	This follows the law of reflection. For every incident ray there is one and only one reflected ray and that angle i = angle r. For both of these to be true, the only position that works is image 3. The opening is so small that only one ray can enter thus allowing for only one image.
NOT...	**A**	This cannot be correct because the ray from 1 would have to reflect backwards to get to the opening.
	B	Position 2 is located on the normal that would be constructed for the ray entering the opening.
	D	This location creates far too large an angle to reflect through the hole

Main Topic: - Law of reflection
Related Topics: - Reflection off multiple surfaces, field of view.

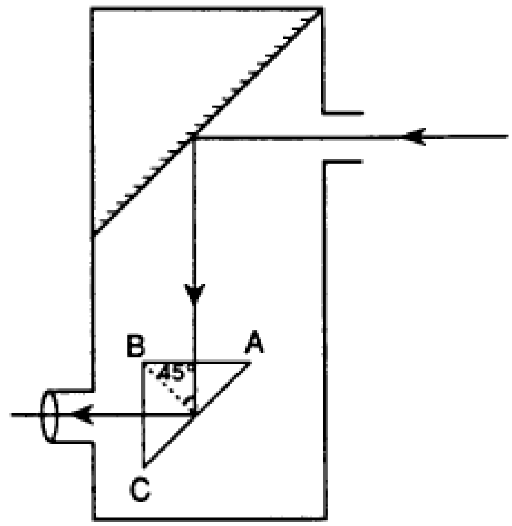
Question 6 — *SMILE FOR THE CAMERA*

A right prism ABC is located at the bottom of a periscope as shown in the diagram to the right. Light passing through the prism is subjected to total internal reflection.

Which of the following could be the index of refraction of the prism?

A) 0.707 C) 1.38

B) 1.26 D) 1.45



		BECAUSE ...
CHOOSE...	**D**	According to the diagram, the angle of incidence is 45°. This angle is greater than the critical angle, θ_c, since there is internal reflection. For total internal reflection to take place, the ray of light must pass from one medium to a less optically dense medium and the angle of incidence exceeds the critical angle. If we calculate the index of refraction using the angle of 45° as θ_c, we will have a value that is close to the actual one. The value of n in this case is 1.41. The relationship between critical angle and index of refraction is inverse. Since the real θ_c is smaller than 45°, the real index must be larger. That is to say, 1.45.
NOT...	**A**	If you remembered something about using sin, you would get 0.707. You must use the entire Snell's law equation to get it right.
	B	This value is below the calculated value. You could also try to determine the θ_c for this index. The angle would turn out to be greater than 45° and would not create internal reflection.
	C	As for B

Main Topic: - Critical angle
Related Topics: - Snell's Law, fiber optics, optical devices.

Question 7 — *THE POWER OF OPTICS*

Two thin lenses are placed together to form an effective lens system. The lenses have powers of 20.0 and –12.0 diopters respectively.

What is the focal length of the lens system?

A) 12.5 cm

B) 8.00 cm

C) 3.13 cm

D) –3.33 cm

		BECAUSE ...
CHOOSE...	**A**	The formula for this question is $P_T = P_1 + P_2 + \ldots$ To find the focal length of the system, you start by adding the two powers given. $P_T = P_1 + P_2 = 20.0 + -12.0 = 8.0$ diopters. You're not finished. Focal length and power are not the same. f = 1/P (answer is in meters). So, f = 1/8 d = 0.125 m = 12.5 cm.
NOT...	**B**	This answer is a trap. As above, when you add the powers, your answer is 8. Looks like choice B but you forgot to use the second formula.
	C	You selected this answer because you followed the proper equations, only you forgot to use the negative sign. This got you to 32 diopters, etc.
	D	To choose this answer, you unfortunately did the equations in reverse. The data given was the optical power not the focal lengths. By making this error and doing the reciprocals first, you would mistakenly end up at choice D.

Main Topic: - Optical power equations
Related Topics: - Focal lengths, converging and/or diverging lenses.

Question 8 — *PLAIN PLANE MIRROR QUESTION*

An object is placed 1 m in front of a plane mirror. A person is located 2 m behind the object.

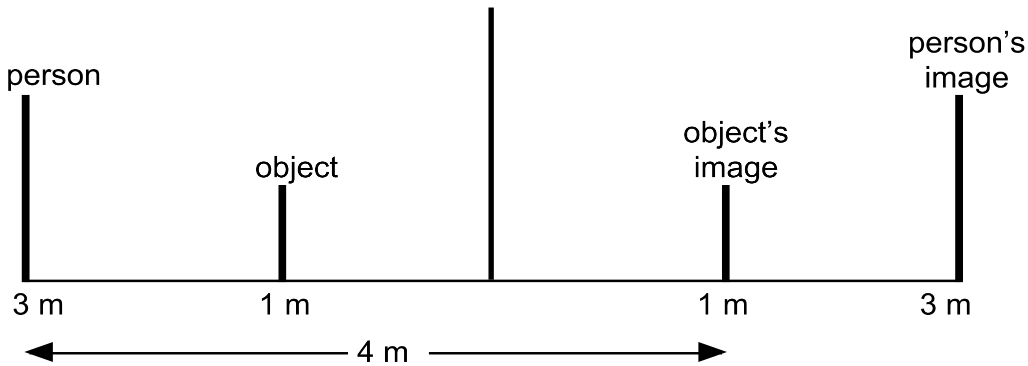
What is the distance between the person and the image of the object?

A) 2 m

B) 3 m

C) 4 m

D) 6 m

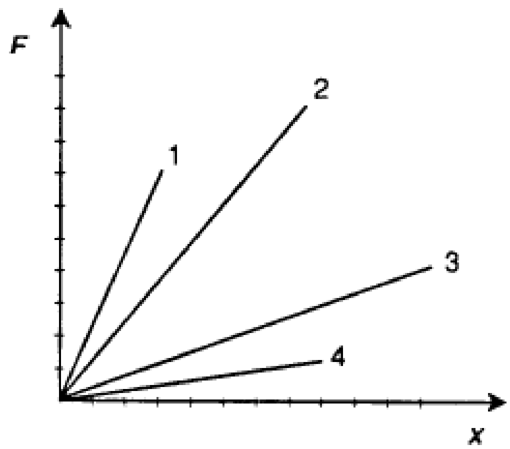


		BECAUSE ...
CHOOSE...	**C**	The easiest explanation is to show the answer on a diagram. By setting up the placements in front of the mirror, the law of reflection off a plane mirror dictates that the images are equidistant to the mirror. The person is 2 m behind the object, which puts him (2+1) = 3 m away from the mirror. The object's image is 1 m away (behind the mirror). Therefore, the distance between them is 3 + 1 = 4 m.
NOT...	**A**	You've misread the question. You are not trying to find the distance between the object and its image. (not 1 m + 1 m)
	B	You've misread the question, again. The person is 2 m behind the object not 2 m away from the mirror. (not 2 m + 1 m)
	D	You've misread the question, again. The question is not looking for the distance from the person to his own image. You have correctly positioned both but are not answering the question that was set.

Main Topic: - Images in a plane mirror
Related Topics: - Image characteristics

Question 9 — ***THIS ONE'S A TOUGH STRETCH***

Four different springs are stretched during a laboratory experiment. The graph below shows the force, *F*, exerted on each spring as a function of the elongation, *x*, of each of them.



Which spring is the stiffest?

A) 1

B) 2

C) 3

D) 4

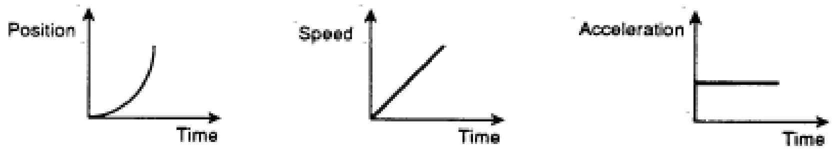
	BECAUSE ...
CHOOSE...	**A** Which spring is the stiffest means: which spring stretches the least or which spring has the least elasticity? A stiff spring requires a large force to extend the spring over a short distance. That is a large F over a small x. F/x is the slope of the graph. You must choose the steepest slope, line 1, choice **A**.
NOT...	**B or C** Neither of these graphs are "the most" as related to slope. Line 2 does reach the highest force while line 3 reaches the longest elongation, neither of these two meet the definition of spring strength, force to extension ratio. **D** This graph has the lowest slope. That can be interpreted as needing a small force to cause a large extension. If you are careless, you might choose this answer.

Main Topic: - Hooke's law
Related Topics: - Graphical interpretation

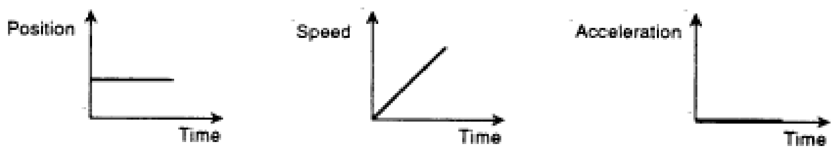
Question 10 — *“PICTURING” MOTION ON A GRAPH*

An automobile is travelling at a constant speed along a highway.
Which set of graphs illustrates the motion of the automobile?

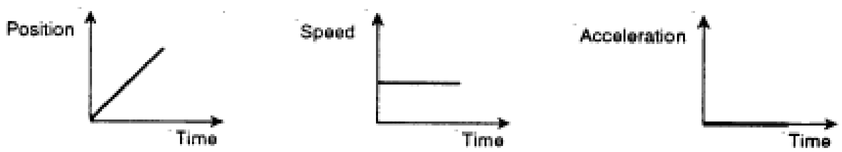
A)



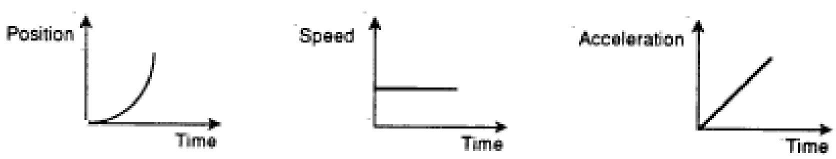
B)



C)



D)



		BECAUSE ...
CHOOSE...	**C**	You must translate the meaning of “constant speed” to predict the graphs. First, constant speed means that you travel the same distance each unit of time; position increasing uniformly. Therefore, the position-time graph must be direct linear. Second point, since the speed is constant and not changing, therefore, the v-t graph is a flat line. And finally, since there is no change in speed, by definition, there is no acceleration. The graph for a-t must show zero. Only choice **C** has all these three graphs represented correctly.
NOT...	**A**	All three graphs describe an object that is accelerating at a constant rate.
	B	The position graph is properly interpreted as no motion and the speed time graph shows a steady increase in speed. You could slip up if you mixed these two up.
	D	Each graph represents different types of motion. The position-time graph shows acceleration, the speed-time graph shows constant speed and the acceleration-time graph shows an increasing acceleration. All wrong.

Main Topic: - Graphical representation of motion.
Related Topics: - Basic kinematics, determination of slope/area for getting speed and/or distance.

Question 11 — *FORCED TO DO THIS ONE*

An object is accelerated by a constant force.

Which of the following statements is FALSE?

A) The acceleration of the object is directly proportional to the net force.

B) The acceleration of the object is inversely proportional to its mass.

C) The acceleration of the object is in the same direction as the net force.

D) The acceleration of the object increases because of the net force.

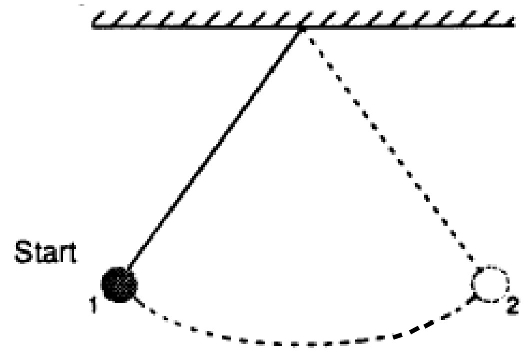
NOTE: for this question you must choose the **incorrect** statement

		BECAUSE …
CHOOSE…	**D**	A constant force causes a mass to accelerate at a constant rate. That's the theory (Newton's 2nd). This statement says that the acceleration increases. Not true, the acceleration remains constant while it is the velocity that increases.
NOT…	**A**	Since the formula is **F = ma**, it can be seen that **a** does vary directly with **F**.
	B	For a constant force, as the mass increases, the rate at which the object can be accelerated is reduced. That is in fact an inverse relationship.
	C	Both force and acceleration are vector quantities. When the force pulls in a specific direction the object has an acceleration in that direction.

Main Topic: - Newton's 2nd law
Related Topics: - All the laws of dynamics, formula relationships

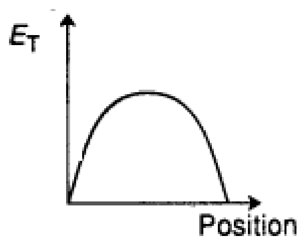
Question 12 *GET IN THE SWING FOR THIS ONE*

The diagram at the right shows the motion of a clock pendulum as it oscillates, without friction, between points 1 and 2.

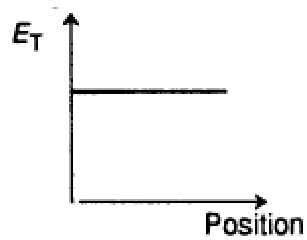


Which of the following graphs represents the total mechanical energy, E_T, or the pendulum as a function of its horizontal position?

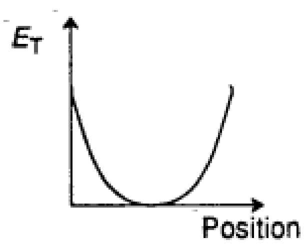
A)



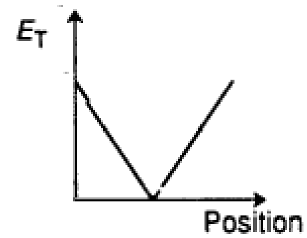
C)



B)



D)



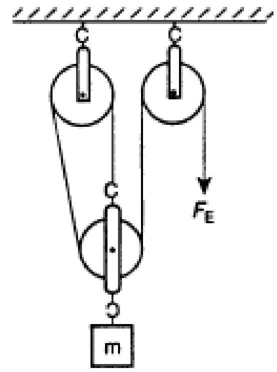
	BECAUSE ...
CHOOSE...	**C** $E_T = E_g + E_k$ E_T = mass x gravity x height + 1/2 mass x velocity^2 $E_T = mgh + 1/2\ mv^2$. This is the basis for this problem. Since there is no friction, no energy should be lost. The mechanical energy is made up of both potential energy, E_g, and kinetic energy, E_k. E_g is found when the pendulum is above its lowest level, it is maximum at points 1 & 2. E_k is found when the pendulum is swinging between points 1 & 2. As the pendulum leaves point 1, the process of converting E_g to E_k begins. The amount lost in E_g, is the amount gained in E_k. This means that the total amount of mechanical energy stays the same. As the pendulum continues its swing, more E_g is lost as more E_k is gained until there is only E_k. This occurs when it reaches bottom.

		BECAUSE ... (continued)
CHOOSE...		The process is reversed as it rises on the other side. Now E_k is converted back to E_g. But through all these changes, the total amount of energy remains the same. The only graph that shows **no** change in E_T is graph **C**.
NOT...	**A**	The first thing wrong with this graph is that it begins and ends at 0. It is the E_k that is 0 at these two positions. This graph is in fact the graph for the E_k **only**, and not the E_T.
	B	This graph starts and ends at a maximum value. That is true for the E_g. But now the graph curves. That suggests a parabolic (x^2) relationship to the height. The formula for E_g is simply $E_g = mgh$. This is a **direct** relationship and should be a straight line graph, not curved. So, not only does it not represent the mechanical energy, it is also wrong for E_g
	D	This is the graph for the loss and gain of E_g. (see above explanation) and not one for mechanical energy.

Main Topic: - Conservation of energy
Related Topics: - Individual equations for E_g and E_k, graphical interpretations.

Question 13 *THIS ONE'S GOT A LOT OF PULL(EYS)*

A system of pulleys is illustrated at the right.



What is the mechanical advantage of this system?

A) 1

B) 2

C) 3

D) 4

	BECAUSE ...
CHOOSE...	**C** A system of pulleys is considered to be a simple machine, Such machines reduce the force required to lift heavy objects. The principle of a pulley system or simple machine is that it is preferable to apply a small effort force through a large distance rather than having to lift heavy loads through a small distance. For a pulley system, the mechanical advantage arises from the number of ropes that are supporting the mass. By counting **only** those ropes involved, there are 3. The third pulley, (top right) is only there to redirect the force, as well as, to confuse you.
NOT...	**A** As described above, it must be the 3 ropes supporting the mass. **B** As described above, it must be the 3 ropes supporting the mass. **D** If you count **each** rope in the diagram, you would get this answer of 4. The final rope leading to F_e is not in fact involved in lifting the mass.

Main Topic: - pulleys
Related Topics: - mechanical advantage, ideal and real

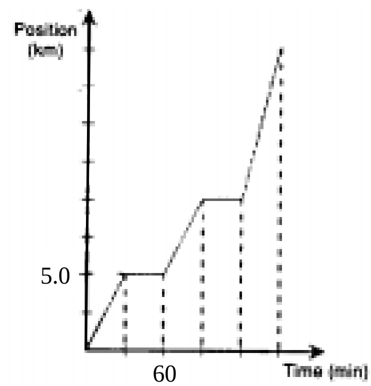
Question 14 — *ALONG A BIKE TRIP*

A cyclist's trip is divided into five stages of 30 minutes each.

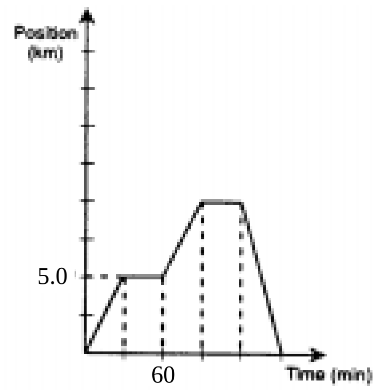
1. He travels 5 km towards the east at a constant speed.
2. He rests.
3. He travels 5 km towards the east at a constant speed.
4. He rests.
5. He travels 10 km towards the west at a constant speed.

Which of the following graphs shows the position of the cyclist as a function of time?

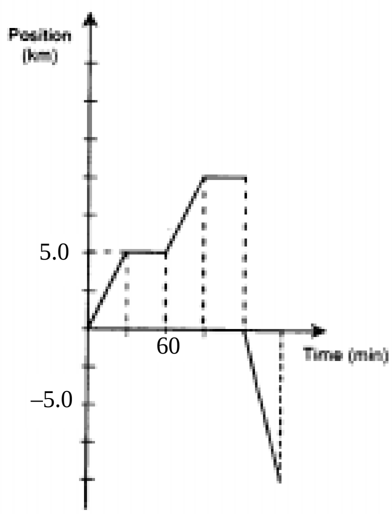
A)



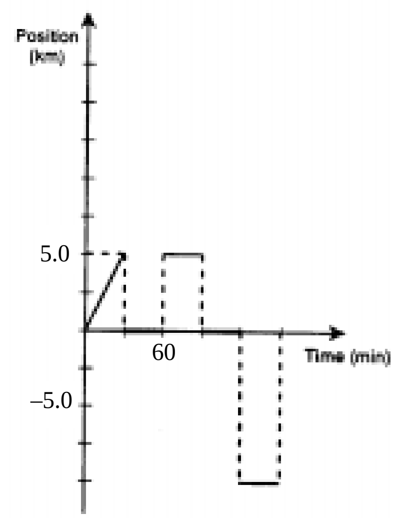
C)



B)



D)



	BECAUSE …
CHOOSE…	**C** The proper **position** (displacement)-time graph is the one that shows the 5 different sections of the trip. This must include the 2 rest stops and the movement in the 2 different directions. The 2 rest stops would appear as flat lines, whereas the east movement would 'go up' while the west movement would 'go down' on the graph. Also, the 10 km east are countered by the 10 km west, which brings the cyclist back to his origin. Graph **C** shows all these things.
NOT…	**A** This answer is great up until the last segment. It shows that the cyclist continued **east** another 10 km. If the graph were just **distance-**time, it would be correct. **B** This answer is also good up until the cyclist starts to head west. You cannot split up the graph and begin again from the x-axis. The movement indicated is 10 km west but it also implies that he was at the starting point after having travelled 10 km east. I don't think so. **D** This graph is trying to get you by plotting what might appear to be the constant **velocity** of each section. Well, the shape is almost correct (first segment is wrong) but the values for velocity are actually wrong. Even though this is a trap, there are enough wrong things about it for you to avoid it.

Main Topic: - Graphing of motion- displacement vs. time
Related Topics: - Graphs of motion, basic kinematic theory.

Question 15 — *A MATTER OF WEIGHT*

An astronaut and her equipment have a total weight of 2940 N on Earth. The astronaut travels to another planet where an object in free fall accelerates at 2.3 m/s^2.

What is the total weight of the astronaut and her equipment on this planet?

A) 3.0×10^2 N

B) 6.9×10^2 N

C) 1.3×10^3 N

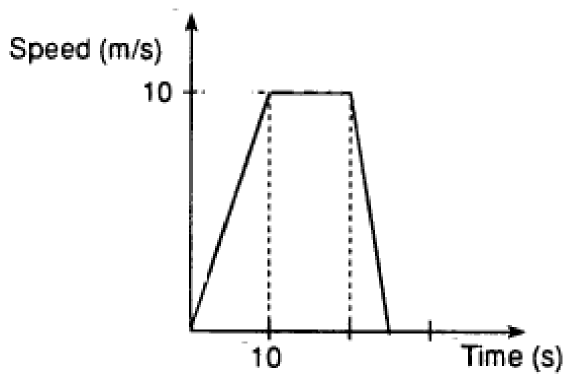
D) 2.9×10^3 N

	BECAUSE ...
CHOOSE...	**B** The astronaut's **mass** <u>not</u> her weight is what is transferred between planets. You must first calculate her mass on earth and then take it to the other planet and recalculate her new weight. Use the formula $F_g = mg$ $m = F_g/g = 2940$ N/9.8 N/kg = 300 kg. Now take her 300 kg to the new planet and recalculate with the value for 'g' on that planet.. Fg = 300 kg x 2.3 m/s^2 = 690 N
NOT...	**A** You got this answer by doing the first part of the question. You found the mass and misread it as the new weight. **C** To arrive at this answer, you used the correct formula but used the weight from **Earth** and the **g** from the other planet and ended up with an answer that is **mass.** Sorry, you can't take your **weight** to another planet nor does the question ask for her new **mass**. Two wrongs did not get you a **right** this time. **D** This choice is for those of you who remembered that something stayed constant from planet to planet but unfortunately it is **not** the weight.

Main Topic: - Weight vs. Mass
Related Topics: - "weightlessness", "elevator" questions

Question 16 *HOW FAR WAS THAT?*

The following graph shows the speed of an object as a function of time.



What distance did the object travel during the first 25 seconds of motion?

A) 20 m

B) 125 m

C) 175 m

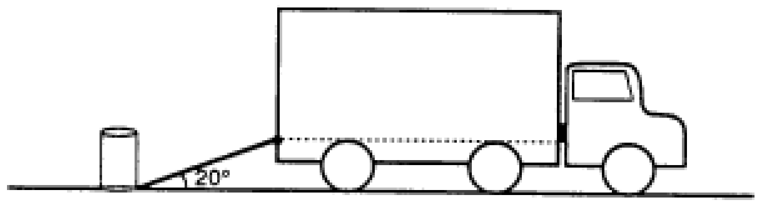
D) 250 m

	BECAUSE ...
CHOOSE...	**C** To get distance, you have to calculate the area under the graph. Area of a triangle = 1/2 base x height Area of a rectangle = Length x width When you do this correctly for the 3 sections you get an answer of 175 m. area 1 = 1/2 x 10 x 10 = 50 m area 2 = 10 x 10 = 100 m area 3 = 1/2 x 10 x 5 = 25 m for a total of 175 m. The alternate method of using the area of a trapezoid works just as well. area = $(b_1 + b_2)/2$ x h = (10 + 25)/2 x 10 = 175 m.
NOT...	**A** You got 20 m by misreading the graph as a displacement - time graph instead of the speed - time graph that it is. **B** If you treat the **whole** graph like a triangle, which it is not, you would get this wrong answer. Look again, it has three distinct sections which must be done individually then added together. **D** If you decided to read the graph as an average speed of 10 m/s for the entire 25 sec, you would get this answer. Again, as described above, there are 3 sections of motion, an acceleration, a constant speed followed by a deceleration.

Main Topic: - V - t graphs and calculating distance/displacement
Related Topics: - Interpretation of kinematic graphs.

Question 17 — *WORK ON THIS LOAD*

An inclined plane is used to load a 120 kg barrel of oil onto a truck. The inclined plane is 5.0 m long and forms an angle of 20^o with the horizontal.



What amount of work is required to load the barrel onto the truck? (Neglect friction.)

A) 2.1×10^2 J

B) 2.0×10^3 J

C) 5.5×10^3 J

D) 5.9×10^3 J

	BECAUSE …
CHOOSE…	**B** Since no work is lost to friction, the work done in lifting the barrel is all converted to the barrel's final E_g. As E_g = mgh, the only thing that is missing from this equation is the height. Using trig, the height can be obtained from the following sin 20^o = x(height)/5 m . It follows then that- x(height) = 5 m sin 20^o= 1.71 m Then, the E_g (work done) = 120 kg x 9.8 m/s^2 x 1.71 m = 2011 J = 2.0 x 10^3 J Another more challenging approach would be to calculate the force that is acting along the incline, $F_i = F_g \sin \theta$, and this value in the work equation along the full length of the ramp.
NOT…	**A** If you assumed the 120 kg to be the 'force' needed to move the barrel then even though you used the correct angle, you would get this incorrect answer. Remember, that you are lifting against the object's **weight** not its mass. **C** If you analyzed this question and arrived at the idea of using the ramp' angle, that's great but you used cosine instead of sine. **D** Not taking into account the angle and using a force equivalent to its weight is the problem here. Using a force of (120 kg x 9.8 m/s^2) = 1176 N is only correct if you are **lifting** the barrel **vertically** and not pushing it over the 5 m length of the ramp.

Main Topic: - Interchange of work and E_g
Related Topics: - Conservation of energy, work and the inclined plane

Question 18 — *THE ENERGETIC SPACESHIP*

A spaceship has a total mass of 2000 kg. It is travelling at an altitude of 100 m above the surface of the moon at a constant speed of 30.0 m/s. Gravitational acceleration on the moon is 1.62 m/s^2.

What is the total mechanical energy of the spaceship relative to the surface of the moon?

A) 3.24×10^5 J

B) 3.54×10^5 J

C) 9.00×10^5 J

D) 1.22×10^6 J

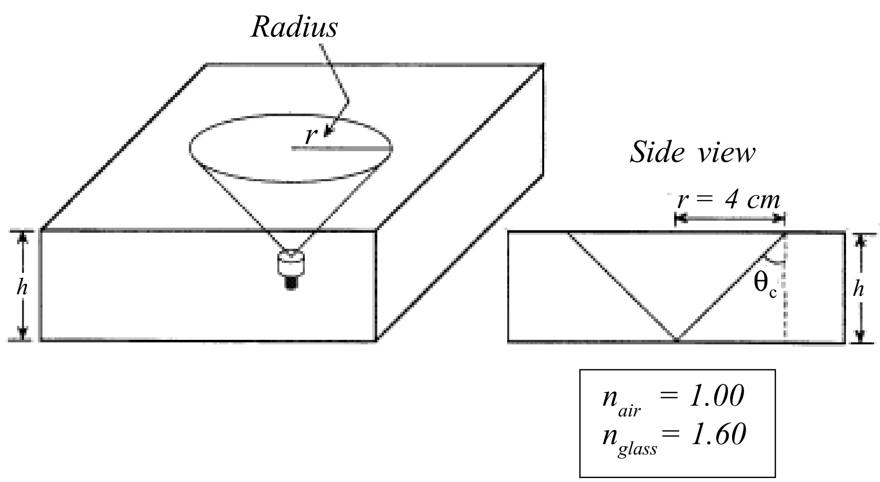
		BECAUSE ...
CHOOSE...	**D**	Mechanical energy is defined as both kinetic and potential energy of an object. Using the speed to calculate the spaceship's Ek and then using the altitude along with the moon's 'g' to calculate its Ep, it is a straight forward process to get this correct answer. $E_k = 1/2\ mv^2 = 1/2 \times 2000\ kg \times (30.0\ m/s)^2 = 900000\ J$ $E_g = mgh = 2000\ kg \times 1.62\ m/s^2 \times 100\ m = 324000\ J$ By adding these two values, you get the total mechanical energy- $= 900000\ J + 324000\ J = 1224000\ J = 1.22 \times 10^6\ J$
NOT...	**A**	This is only a partial answer. All you have calculated so far is the **correct** E_g. Read again and you'll see that you need the **extra** E_k due to its motion
	B	You got here by doing the question almost perfectly. You recognized the need for the two forms energy and you've used the correct value for 'g'. Only one little problem. You **forgot** to square the speed in calculating the E_k. **OOPS!**
	C	As with choice A, you calculated half of the answer. This value is **only** the E_k. You still need the E_g. Sorry.

Main Topic: - Mechanical energy
Related Topics: - E_k, E_g and the conservation of energy.

Part B - Constructed Answer

Question 19 **BENDING THROUGH THE BLOCK**

A glass block in the shape of a rectangular prism with a square base is shown in the diagram below. A point source of light is placed at the centre of the base (the bottom) of the prism. The rays emerging from the block form a circle on the upper surface of the block. The other rays undergo total internal reflection in the glass.



According to the information given in the diagram, what is the height of the block?

ANSWER: **height of block = 5 cm**

Once the shock of reading the question is over, we focus on the side view diagram. It shows us the widest beam of light that can escape from this glass prism. Any rays that are beyond this "**V**' shape, internally reflect.

As indicated in the diagram, the outside of this 'cone of light' forms the critical angle inside the prism. This is where the question truly begins.

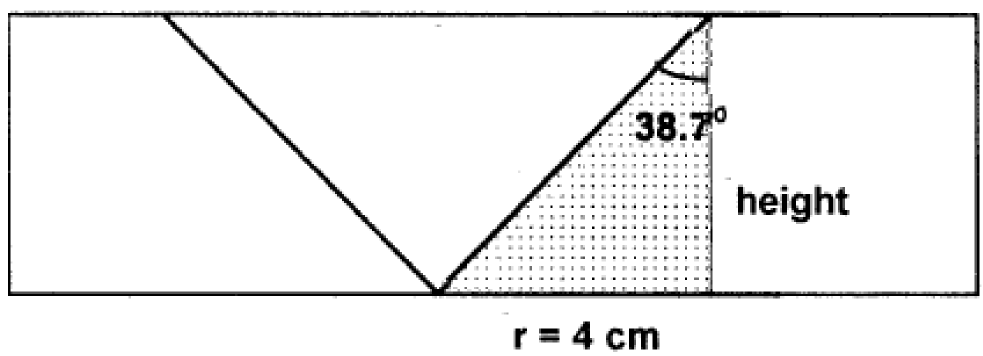
You must use Snell's law, the indices of refraction, and the θ_c.

We have two equations available:

$$
\begin{aligned}
(n_1)(\sin\theta_1) &= (n_2)(\sin\theta_2) \quad \text{or} \\
\sin\theta_c &= 1/n \quad \text{(since the second material is air)}
\end{aligned}
$$

$$
\begin{aligned}
(1)(\sin 90^o) &= (1.60)(\sin\theta_c) \\
1/1.60 &= \sin\theta_c \\
0.625 &= \sin\theta_c \\
\theta_c &= 38.7^o
\end{aligned}
$$

Using this angle in the triangle, which includes the height of the block and the radius(4 cm) as the base, we can calculate the value of “h”.



To solve for the height, use tan θ

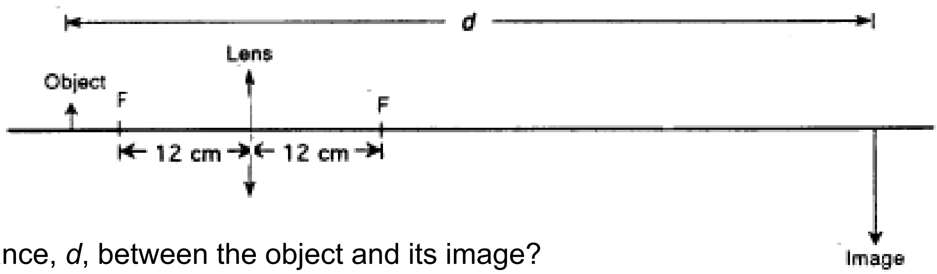
tan θ	=	opp/adj
tan 38.7°	=	4/h
h	=	4/tan 38.7°
h	=	4/0.800
h	=	5 cm

Main Topic: - critical angle

Related Topics: - Snell’s Law, trigonometry

Question 20 — *FOCUS ON THIS LENS PROBLEM*

The height of a certain object is 2.0 cm; the height of its image formed by a thin converging lens is four times as great. The focal length of the lens is 12 cm.



What is the distance, *d*, between the object and its image?

***ANSWER*:** **distance between the objects = 75 cm**

If this diagram was drawn to scale, you could measure the 'd' from object to image directly. As careful as the diagram is set up, it is **not** to scale and should have been indicated as such.

To **calculate** the answer requires using the two lens equations and the fact that-

$h_i = -4h_o$ ("image ...four times greater" and negative because it's real))

but also

$$h_i/h_o = - d_i/d_o$$
$$(-4h_o)/h_o = - d_i/d_o$$
$$d_i/d_o = 4$$
$$d_i = 4d_o$$

Having been given the value of 'f', we now use the second equation.

$$1/f = 1/d_o + 1/d_i$$
$$1/12 = 1/d_o + 1/4d_o$$
$$1/12 = 5/4d_o$$
$$d_o = (5)(12)/4$$
$$d_o = 15 \text{ cm}$$

but $d_i = 4d_o$

so $d_i = (4)(15)$

$$d_i = 60 \text{ cm}$$

d (dist. from obj to image) $= 15 \text{ cm} + 60 \text{ cm}$
$= 75 \text{ cm}$

Main Topic: - lens equations
Related Topics: - image locations, image formation

Question 21 — *MIRROR, MIRROR*

A certain object is placed 30 cm from a concave mirror. You observe a real image 15 cm from the mirror. You then move the object to a position 6.0 cm from the mirror.

How far is the new image from the mirror?

Specify whether the image is located in front of or behind the mirror.

ANSWER: **distance of the image = 15 cm**
located behind the mirror (since the actual answer is -15 cm)

The values given, do = 30 cm and di = 15 cm, allow us to calculate the value of the focal length.

$$
\begin{aligned}
1/f &= 1/d_o + 1/d_i \\
1/f &= 1/30 + 1/15 \\
1/f &= 3/30 \\
1/f &= 1/10 \\
f &= 10 \text{ cm}
\end{aligned}
$$

Recalculate with the new d_o.

$$
\begin{aligned}
1/f &= 1/d_o + 1/d_i \\
1/10 &= 1/6 + 1/d_i \\
1/d_i &= 1/10 - 1/6 \\
1/d_i &= -4/60 \\
1/d_i &= -1/15 \\
d_i &= -15 \text{ cm}
\end{aligned}
$$

Since the d_i is negative, this indicates that the image is **behind** the mirror. This is also verified by the fact that the d_o is less than the focal length. This places it in the “magnifying/shaving mirror’ position.

Main Topic: - mirror equations
Related Topics: - virtual/real images

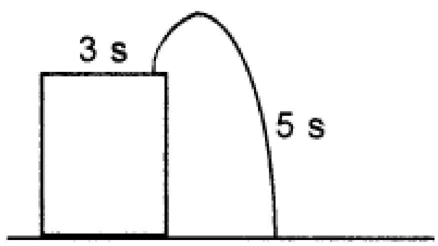
Question 22 ***WHAT GOES UP MUST COME DOWN.***

Standing on the edge of the roof of a building, you throw a stone vertically upward. The stone rises for 3.0 s, then falls for 5.0 s before hitting the ground right beside the foundation of the building. Air resistance is negligible.

What is the height of the building?

ANSWER: **height of the building = 78.4 m**

The stone will follow a parabolic path. It will 'stay' in the air for a total of 8 seconds.



To calculate its displacement, use the appropriate equation substituting the value of 'g' for the acceleration.

$$\Delta d = v_1 \Delta t + 1/2a\,(\Delta t)^2$$

To determine v_1, we first use the fact at its maximum height it will stop before falling back to earth. For that portion of its movement:

$v_2 = v_1 + g\Delta t$
(v_2 is equal to 0 at the top of the trajectory)
$0 = v_1 + (-9.8\ m/s^2)\ (3\ s)$
$0 = v_1 + -29.4\ m/s$
$v_1 = 29.4\ m/s$

We can now use this value in the first equation; using the full 8 seconds.

$\Delta d = v_1 \Delta t + 1/2a(\Delta t^2)$
$\Delta d = (29.4\ m/s)(8\ s) + 1/2(-9.8\ m/s^2)(8\ s)^2$
$\Delta d = 23.5.2\ m + (-313.6\ m)$
$\Delta d = -\ 78.4\ m$

This indicates that from its original position it fell downwards 78.4 m, which would be the height of the building.

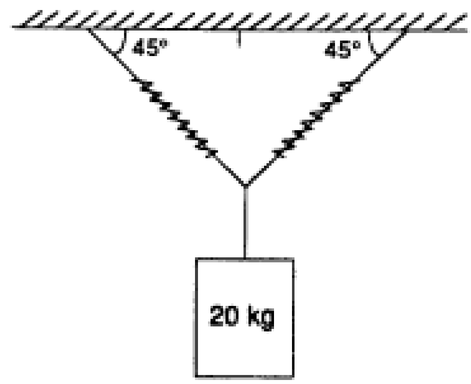
The question can also be done dividing the trajectory into up and down segments. Then determine the height to which the stone rises and follow that with the distance it falls. All methods will lead to 78.4 m.

Main Topic: - acceleration due to gravity
Related Topics: - kinematic equations, "up and down" situations

Question 23 — *SPRING INTO ACTION*

A mass of 20 kg is suspended from two identical springs as shown in the diagram to the right. Each spring has a spring constant of 500 N/m and a negligible mass.

What is the elongation of each spring?



ANSWER: **the elongation of each spring = 0.28 m**

One method for solving this is as follows. There are 4 steps necessary in solving this problem.

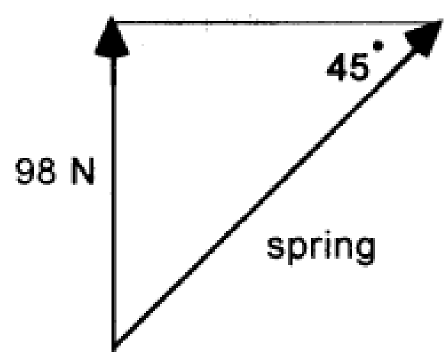
1. the weight of the suspended mass
2. the vertical component for each spring
3. the actual force on each spring and
4. the elongation caused by that force.

Step 1 $F_g = mg$
$F_g = (20\text{ kg})(9.8\text{ m/s}^2)$
$F_g = 196\text{ N}$

Step 2 The total force upward must be 196 N to maintain equilibrium. Each spring supplies 1/2 of this 196 N, that is, 98 N each upward, since it is symmetrical.

step 3 By using the appropriate trig function, the force on each spring can be determined.

sin 45°= 98 N/force on spring
force on spring = 98 N/ 0.707
force on spring = 138.6 N



and finally...

Step 4

F	= k x
138.6 N	= (500 N/m)(l)
x	= 138.6 N/500 N/m
x	= 0.28 m

Main Topic: - forces in equilibrium, Hooke's Law
Related Topics: - vectors, weight/mass

Question 24 *LET THE MACHINE DO THE WORK*

With the help of a certain machine, you lift a 10 kg mass to a height of 6.0 m. To do this work, you exert a constant force of 40 N through a distance of 24 m.

What is the efficiency of the machine?

ANSWER: **the efficiency = 61%**

From the given information, we can assign values to the input and the output of the machine.

The lifting of the object is the **output.**

$$\begin{aligned} \text{Output force} &= (10\text{ kg})(9.8\text{ m/s}^2) \\ &= 98\text{ N} \\ \text{distance} &= 6.0\text{ m} \\ \text{work(out)} &= (98\text{ N})(6\text{ m}) \\ &= 588\text{ J} \end{aligned}$$

Your participation in the question involves the input.

$$\begin{aligned} \text{Input force} &= 40\text{ N} \\ \text{distance} &= 24\text{ m} \\ \text{work(in)} &= (40\text{ N})(24\text{ m}) \\ &= 960\text{ J} \end{aligned}$$

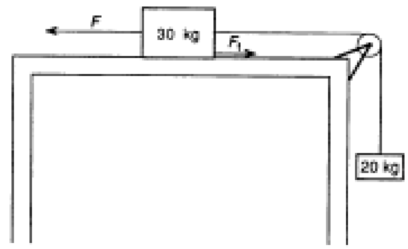
Now that the two amounts of work have been calculated, the efficiency is simply a matter of setting up the ratio.

$$\begin{aligned} \text{Eff} &= \text{work(out)/work(in)} \times 100\% \\ \text{Eff} &= 588\text{ J}/960\text{ J} \times 100\% \\ \text{Eff} &= 61\ \% \end{aligned}$$

Main Topic: - machines
Related Topics: - work formula, effects of friction

Question 25   *HANG IN THERE FOR THIS ONE BECAUSE IT'S THE LAST ONE*

A 30 kg block is resting on a horizontal table. The block is connected by a string to a 20 kg mass as shown in the diagram below. The total frictional force in the system is 50 N. You want to give the system an acceleration of 0.40 m/s^2 to the left.



What force must be applied to the system to give it this acceleration?

ANSWER: **applied force = 266 N**

A truly challenging final question. We have to somehow determine the applied force but this must be done by finding Fnet for this system.

Several other factors are involved, namely: - friction - total mass - direction

The easiest part is the total mass. This step determines the actual mass that will be accelerated.

$$\begin{aligned} \text{mass(total)} &= 30 + 20 \\ &= 50\text{ kg} \end{aligned}$$

This is the mass that the $\mathbf{F_{net}}$ will act on.

$$\begin{aligned} \text{Since Fnet} &= ma \\ \text{and } a &= 0.40\text{ m/s}^2 \textbf{ to the left, } \text{we can determine } F_{net} \text{ (to the left)} \\ F_{net} &= (50)(0.40) \\ F_{net} &= 20\text{ N } (\textbf{to the left}) \end{aligned}$$

Fnet is the result of the applied force**, F**, acting **to the left,** while all the resisting forces are acting **to the right**. In this case, there are two resisting forces.

1. friction and
2. the F_g of the 'hanging mass'

1. $F_f = 50$ N (given)
2. $F_g = mg = (20)(9.8) = 196$ N

$$\begin{aligned} \text{Thus } F_{net} &= F_{applied} - F_{resistance} \quad \text{(opposing the motion)} \\ 20\text{ N} &= F - (50 + 196) \\ F &= 266\text{ N} \end{aligned}$$

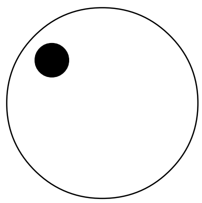
Main Topic: - 'hanging mass' problems
Related Topics: - F_{net}, friction

MODULE 1 (OPTICS)

— ANSWER KEY —

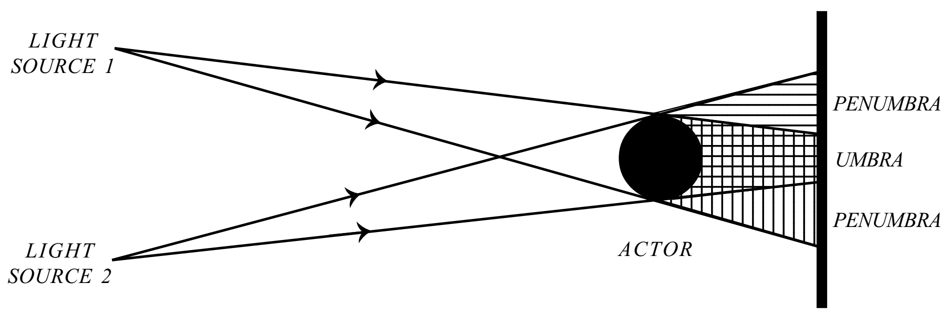
OBJECTIVE 1.1

1. The rays criss-cross as they pass throughthe pinhole (reversal laterally).



OBJECTIVE 1.3

1.

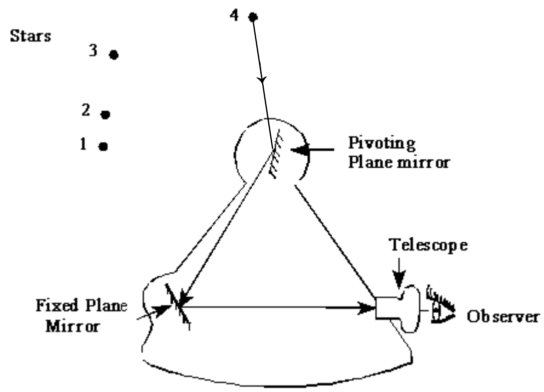


Umbra is the area of overlap of both shadows - darkest area.

2. C) A shadow expands proportionately (point for point) along straight lines.

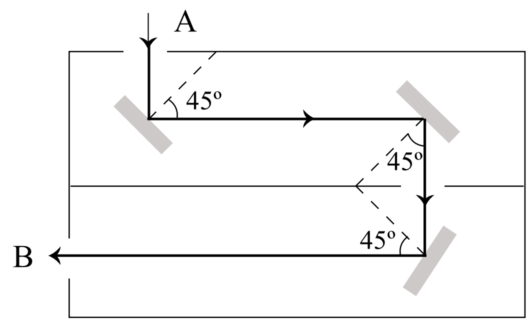
OBJECTIVE 2.2

1. The only star that can be seen is star 4 because it is the only point that will obey the laws of i = r.



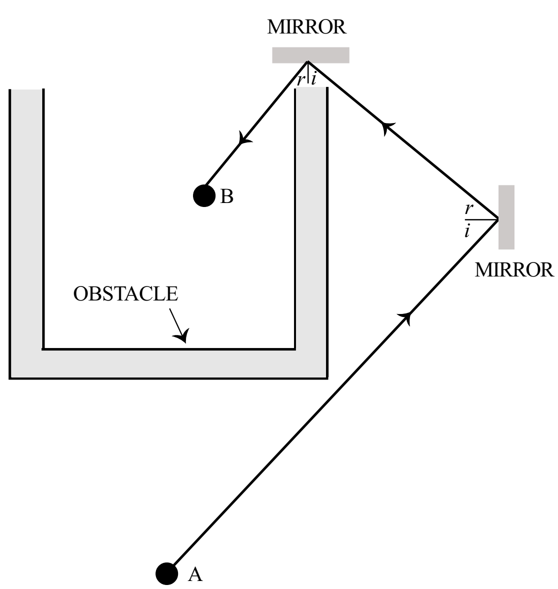
OBJECTIVE 2.4

1.



This diagram places the mirrors at 45 degree angles, however, other answers are possible.

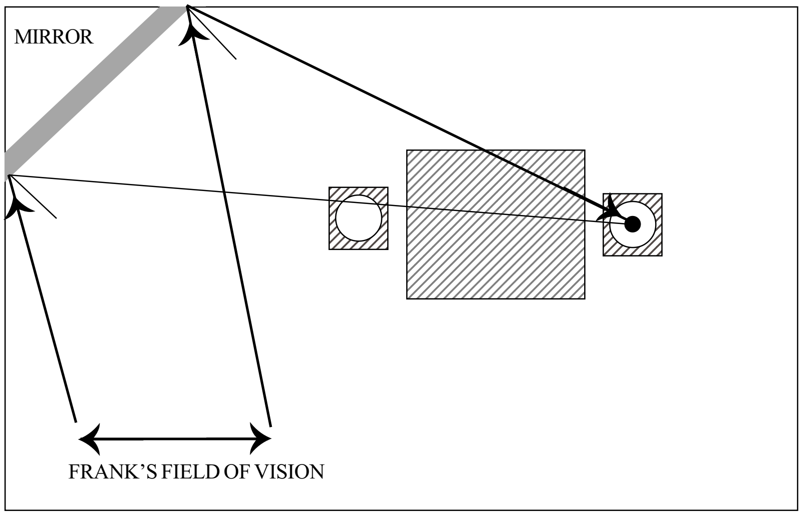
2.



$i = r = 45^0$

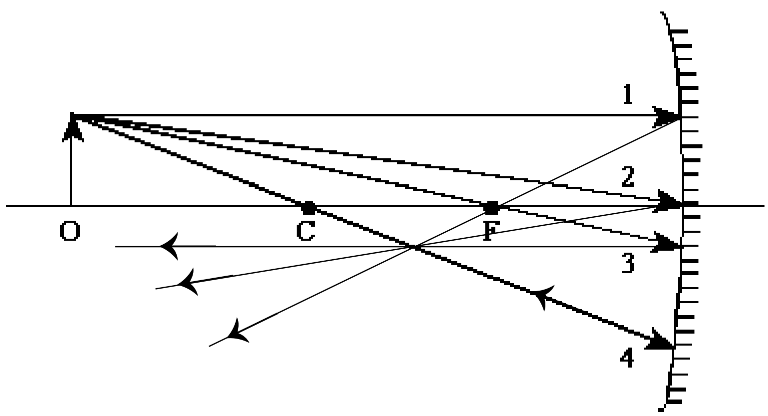
OBJECTIVE 2.5

1. No, Frank cannot see Anne's cards.



OBJECTIVE 2.6
OBJECTIVE 2.10

1.



Ray 1 is parallel to the principal axis, therefore reflects through F.
Ray 2 goes through the vertex, therefore follows laws of reflection of i = r.
Ray 3 goes through F and therefore is reflected parallel to the principal axis.
Ray 4 goes through C and therefore is reflected back along C.

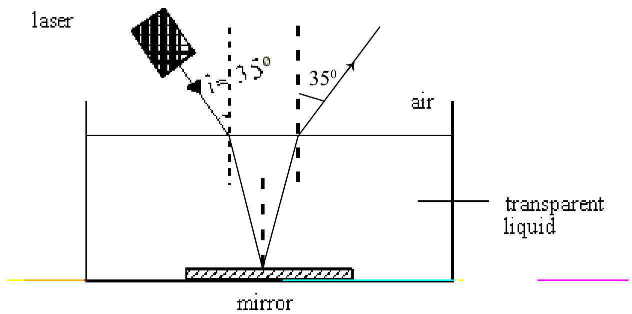
OBJECTIVE 3.1

1. A. Shows bending of light - refraction
   B. “Mirror image” - specular reflection
   C. The diagram is not accurate but it does show bending of light - refraction.
   D. The reflection of the light from the mirrored surface of the headlight - specular reflection.
   E. Shows reflection in many directions - diffuse reflection.

2. D) Parts 1, 3 and 5 refer to reflection.
   Parts 2, 4 and 6 refer to refraction, therefore the answer is D.

OBJECTIVE 3.2

1.



Interface 1: Refraction closer to the normal because going from less dense to more dense medium
Interface 2: i = r reflection in a mirror
Interface 3: As a ray leaves the liquid, it refracts away from the normal back to the original angle of 35º.

OBJECTIVE 3.3

1. Spot #1: must contain blue which is reflected by the sweater and not the pants
   Spot #2: must contain red which is reflected by the sweater and not the pants
   Spot #3: has a green light which is reflected by both the sweater and the pants

   The sweater must be white because it reflects blue, red and green but the pants must be green because they reflect only green light.

2. D) Only blue is reflected by the desktop and the other colours are absorbed.

OBJECTIVE 3.4

1. Given: Incidence angle = 23º
Refracted angle = 32º
Use Snell's Law:

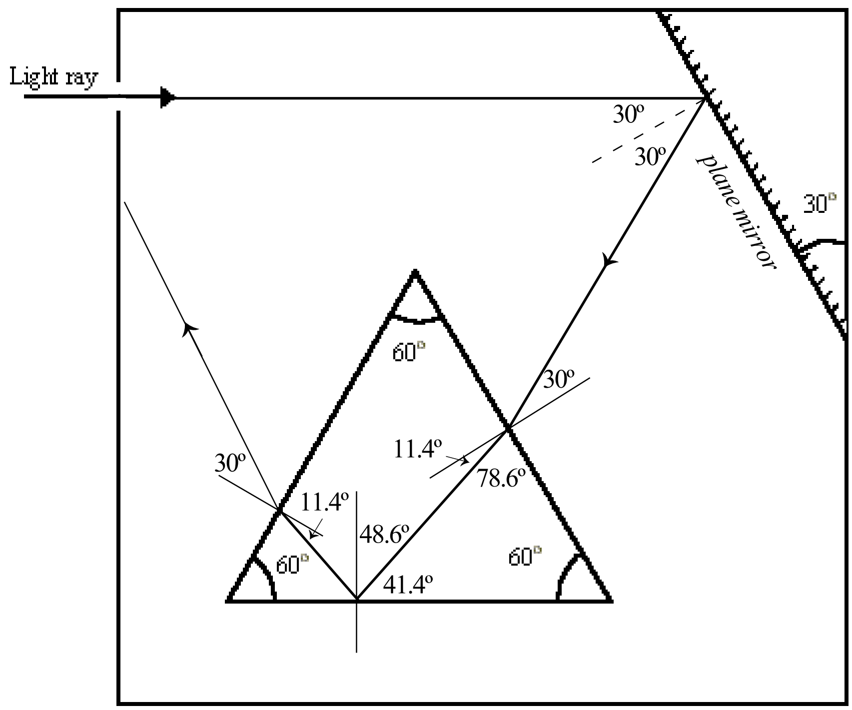
$$n_1 \sin\Theta_1 = n_2 \sin\Theta_2$$

$$n_1 = \frac{n_2 \sin\Theta_2}{\sin\Theta_1} = \frac{1.0 \text{ x } \sin 32^\circ}{\sin 23^\circ} = 1.36$$

The refractive index of sea water is 1.36.

OBJECTIVE 3.7

1.



1. Plane mirror: angle of
incidence = angle of r
$30^\circ = 30^\circ$

2. Refraction from air to
$n_1 \sin\Theta_1 = n_2 \sin\Theta_2$
$1.0 \sin 30^\circ = 2.54 \sin$
$11.4^\circ = \Theta_2$

3. Refraction from prism
$n_1 \sin\Theta_1 = n_2 \sin\Theta_2$
$2.54 \sin 48.6^\circ = 1.0 \text{ si}$
Total internal reflectio
The ray is reflected 48

4. $n_1 \sin\Theta_1 = n_2 \sin\Theta_2$
$2.54 \sin 11.4^\circ = 1.0 \sin\Theta_2$
$30^\circ = \Theta_2$

OBJECTIVE 3.8

1. $n_1 \sin\Theta_1 = n_2 \sin\Theta_2$
   $1.0 \sin A = 1.33 \sin 25^\circ$
   $A = 34.2^\circ$

OBJECTIVE 4.4

1. Given: Total focal length = 50 cm = 0.50 m
   Focal length of converging lens = 20 cm = 0.20 m

   Power of lens combination $P = \dfrac{1}{f}$

   $P = \dfrac{1}{0.50 \text{ m}}$

   $P = 2$ diopters

   Power of converging lens $P = \dfrac{1}{f}$

   $P = \dfrac{1}{0.20 \text{ m}}$

   $P = 5$ diopters

   Power of diverging lens is 2 d – 5 d = –3d.
   Therefore, the power of the diverging lens is –3 diopters.

2. Data given: P_1 = -10 diopters
   P_2 = -6 diopters
   P_3 = 4.0 diopters
   P_4 = 14 diopters
   P_5 = 16 diopters
   f = 50 mm (0.050 m)

   1. Total optical power of the required lens combination

   $$P = \frac{1}{f}$$

   $$P = \frac{1}{0.050 \text{ m}}$$

   $$P = 20 \text{ diopters}$$

   2. One possible lens combination

   $$P = P_1 + P_4 + P_5$$
   $$P = -10.0 \text{ d} + 14 \text{ d} + 16 \text{ d}$$
   $$P = 20 \text{ diopters}$$

   Answer : One possible combination consists of lenses 1, 4 and 5.

OBJECTIVE 4.6

1. Rays 4, 5 and 6 are the correct refracted rays through a convex lens.

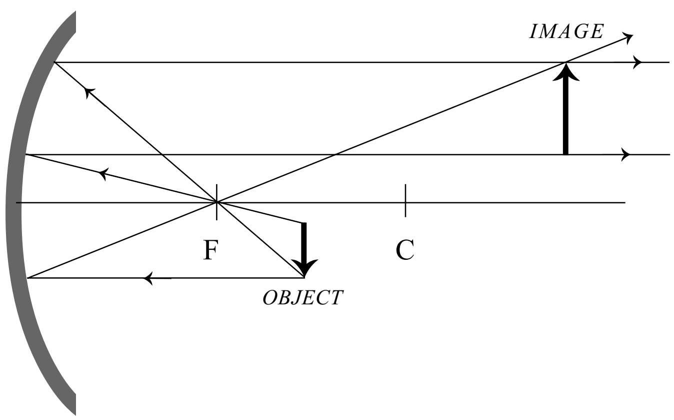
OBJECTIVE 5.1

1. 4 characteristics of the lens: Located between F and 2F, small, real and inverted

OBJECTIVE 5.2

1. Diagrams 1 and 2: The image is found in the correct location, however, it is upside down.
   Diagrams 3, 4 and 5: The image is drawn correctly.

2.



OBJECTIVE 5.3

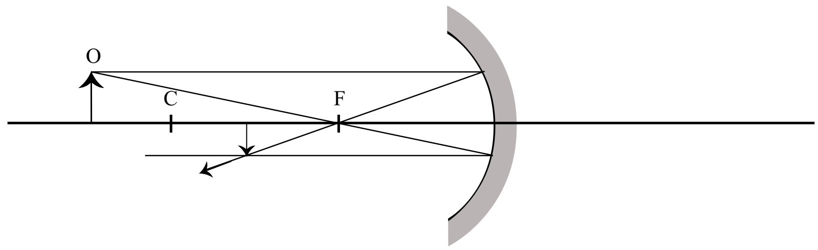
1. Image is located between the focu and the optical centre of the lens.
   It is upright, virtual and smaller than the object.

OBJECTIVE 5.4

1. Two of the following characteristics:
   - The image is upright.
   - The image is virtual.
   - The image is smaller than the object.
   - The image is between the mirror and its focal point.

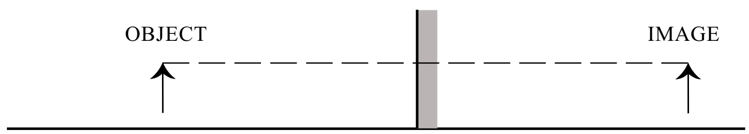
2. The answer is C because with a diverging lens, the image is always found on the same side of the lens as the object, and it is smaller than the object.

3. A)



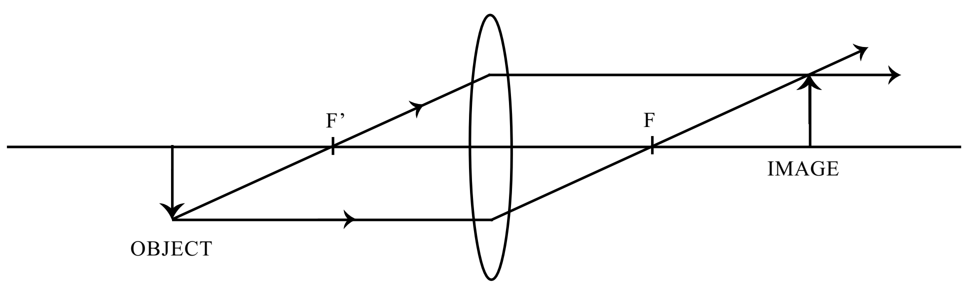
Concave Mirror: Image is smaller than the object.
Image is inverted.
Image is real.
Image is found between C and F.

B)



Plane Mirror: Image is same size as the object.
Image is upright.
Image is virtual.
Image is found behind the mirror.

C)



Convex Lens: Object is upside down so image is upright.
Image is same size as object.
Image found beyond F (at C).
Image is real.

OBJECTIVE 5.5

1. D).

OBJECTIVE 5.7
OBJECTIVE 5.13

1. Given: $h_0 = 8$ cm (0.08 m)
$f = 30$ cm (0.30 m)
$d_0 = 0.70$ m

1. Image distance from mirror:

$$\frac{1}{d_0} + \frac{1}{d_i} = \frac{1}{f}$$

$$\frac{1}{0.70\text{ m}} + \frac{1}{d_i} = \frac{1}{0.30\text{ m}}$$

$$d_i = 0.525\text{ m}$$

2 Height of the image:

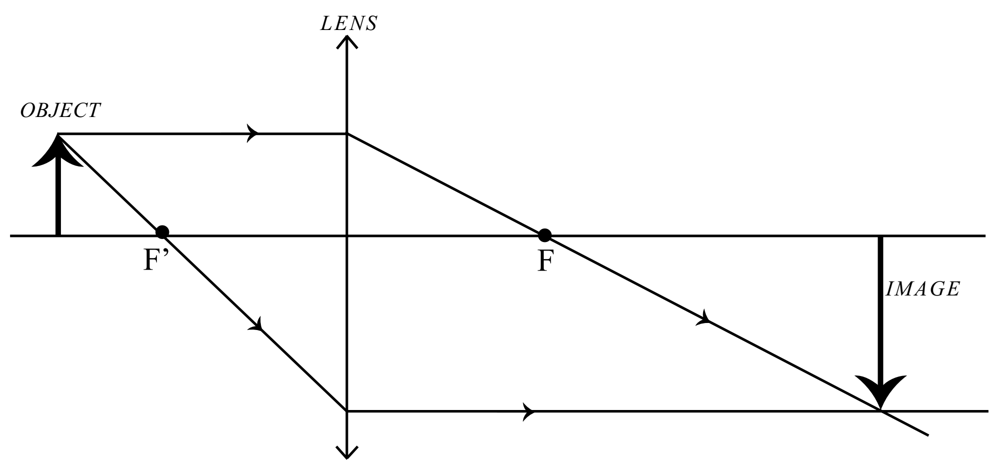
$$\frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

$$\frac{h_i}{0.08\text{ m}} = -\frac{0.525\text{ m}}{0.70\text{ m}}$$

$$h_i = -0.06\text{ m}$$

The height of the image is 6 cm, and the image is inverted.

2. a)



b)

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$\frac{1}{d_i} = \frac{1}{f} - \frac{1}{d_o}$$

$$= \frac{1}{10 \text{ cm}} - \frac{1}{15 \text{ cm}}$$

$$= \frac{1}{30 \text{ cm}}; \qquad d_i = 30 \text{ cm}$$

$$M = \frac{d_I}{d_o} = -\frac{30 \text{ cm}}{15 \text{ cm}} = -2$$

The magnification of this image is –2.

3. 1. Converging lens (magnification for a real image is negative)

$M = -5$

Therefore, $-5 = \frac{d_I}{d_o}$; $\quad d_I = 5d_o$

2. Distance from the lens to the object:

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$\frac{1}{60 \text{ cm}} = \frac{1}{d_o} + \frac{1}{5d_o}$$

$$\frac{1}{60 \text{ cm}} = \frac{6}{5d_o}$$

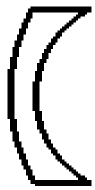
$$d_o = \frac{6\ (60 \text{ cm})}{5}$$

$$d_o = 72 \text{ cm}$$

Answer: She must place the lens 72 cm from the object.

OBJECTIVE 5.9

1. 1. Myopia (near sighted).

   2.  Concave lens.

   3. The light rays diverge.

MODULE 3

— ANSWER KEY —

OBJECTIVE 1.1

1. A

OBJECTIVE 1.2

1. D

OBJECTIVE 1.6

1. $\frac{5}{7}$

2. The total vector displacement is: magnitude : 1000 m
   direction : 307º from horizontal (counterclockwise)

   or

   magnitude : 1000 m
   direction : -53º from horizontal (clockwise)

   Note: Accept an error of ± 2 degrees in value for the direction.

OBJECTIVE 2.3

1. C

2. A

OBJECTIVE 2.4

1. Spring nº 2 is the easiest to stretch.
   When the same force is applied to each spring, it is nº 2 that is stretched the most.

   $$\frac{\Delta x_2}{\Delta F} > \frac{\Delta x_1}{\Delta F}$$

   i.e. compare the slopes which express the rates of change of the length of the springs.

2. 1.2 N

OBJECTIVE 3.1

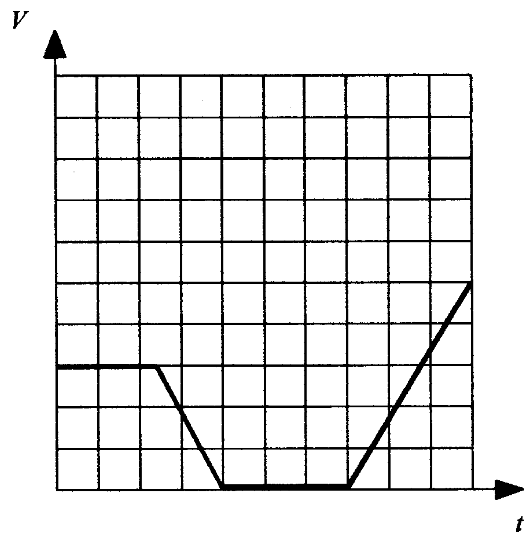
1. B

OBJECTIVE 3.2

1. A

OBJECTIVE 3.3

1.

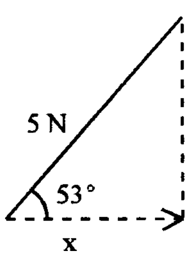


Note: The lengths of the segments may be different from those shown below.

Points to note: 1st segment : 0 slope ($v \neq 0$)
2nd segment : negative slope
3rd segment : 0 slope ($v = 0$)
4th segment : positive slope

OBJECTIVE 3.5

1. Work: Resultant force



$$\frac{x}{5\ \text{N}} = \cos 53^{\circ}$$

$$x = \cos 53^{\circ} \times 5\ \text{N}$$

$$= 0.60 \times 5\ \text{N}$$

$$= 3\ \text{N}$$

F_R : 2x (x) = 2 x 3N = 6 N

Result: Resultant force is 6 N.

2. B

3. <u>Work</u> Examples of appropriate procedures

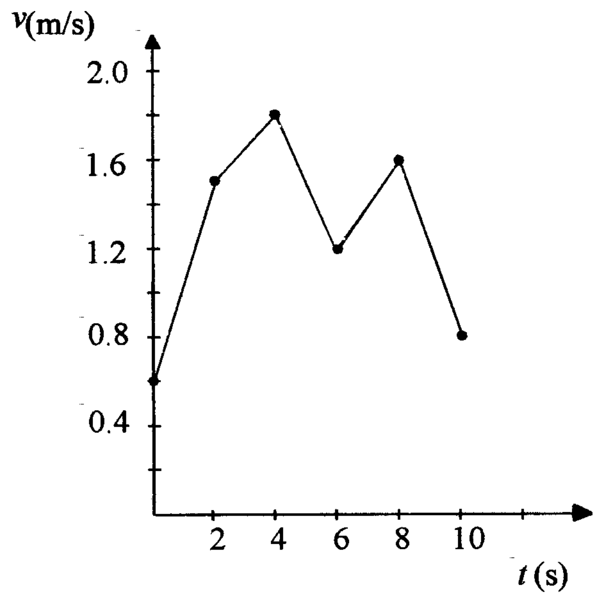
1st Method
Sum of the distances calculated from the average speed for each time interval.

$$\Delta s = (1.05 \times 2) + (1.65 \times 2) + (1.5 \times 2) + (1.4 \times 2) + (1.4 \times 2)$$
$$= 2.1 + 3.3 + 3.0 + 2.8 + 2.4$$
$$= 13.6$$

Result: Distance travelled is approximately 13.6 m.

or

2nd Method
By determining the area under the velocity time graph.



Result: Distance travelled is 13.6 m within 10 %.

OBJECTIVE 3.9

1. <u>Work</u> Examples of appropriate procedures

1st Method
Using equations of motion

$$\Delta \vec{d} = v_i \Delta \vec{t} + \frac{1}{2} \vec{a} (\Delta \vec{t})^2$$
$$= 0 \text{ m/s} \times 0.5 \text{ s} + \frac{-10}{2} \text{ m/s}^2 (0.5)^2 \text{s}^2$$
$$= -1.25 \text{ m}$$

Result: Height is 1.25 m.

2nd Method
Using the area under the velocity / time graph

$$A = \text{area}$$
$$= \frac{1}{2}(v_i + v_f) \bullet \Delta t$$
$$= \frac{1}{2}(0 \text{ m/s} + (-5.0 \text{ m/s})) \bullet 0.5 \text{ s}$$
$$A = -1.25 \text{ m}$$
$$\therefore \Delta d = -1.25 \text{ m}$$

Result: Height is 1.25 m.

2. Example of an appropriate procedure:

1. Calculation of the acceleration

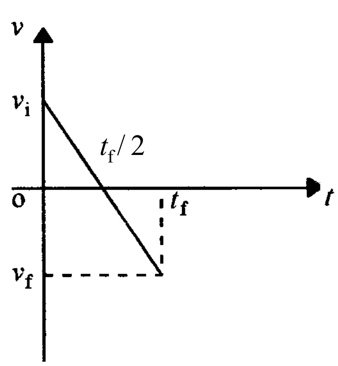
$$\Delta d = v_i \, \Delta t + \frac{1}{2} a \, (\Delta t)^2$$
$$0.10 \text{ m} = 0 \text{ m/s} \bullet 1.0 \text{ s} + \frac{1}{2} \text{a} \, (1.0 \text{ s})^2$$
$$\text{a} = 0.20 \text{ m/s}^2$$

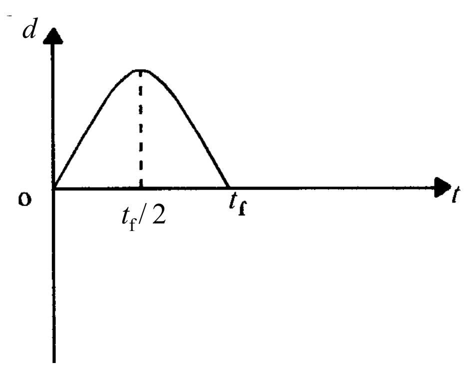
2. Calculation of the distance

$$\Delta d = v_i \, \Delta t + \frac{1}{2} a \, (\Delta t)^2$$
$$\Delta d = 0 \text{ m/s} \bullet 5.0 \text{ s} + \frac{1}{2} \bullet 0.20 \text{ m/s}^2 \bullet (5.0 \text{ s})^2$$
$$\Delta d = 2.5 \text{ m}$$

Result: After 5.0 seconds, the marble will have travelled 2.5 m.

3.





OBJECTIVE 4.1

1. D

OBJECTIVE 4.2

1. Example of an appropriate procedure

   1) Area under the curve (distance covered) for the sports car

      $$\frac{20 \text{ m/s} \bullet 6 \text{ s}}{2} + 20 \text{ m/s } (t - 6\text{s})$$

   2) Area under the curve (distance covered) for the pickup truck

      $10 \text{ m/s} \bullet t$

   3) Time at which the areas under the curves are equal

      $$\frac{20 \text{ m/s} \bullet 6 \text{ s}}{2} + 20 \text{ m/s } (t - 6\text{s}) = 10 \text{ m/s} \bullet t$$

      $$\begin{aligned} 60 + 20t - 120 &= 10t \\ 10t &= 60 \\ t &= 6 \text{ s} \end{aligned}$$

   Result: The sports car will pass the pickup truck when t equals 6 s.

2. B

OBJECTIVE 4.4

1. A

OBJECTIVE 4.6

1. C

OBJECTIVE 5.2 & 5.3

1. Only II and III.

2. D

OBJECTIVE 5.4

1. A

OBJECTIVE 6.1

1. B

OBJECTIVE 6.2

1. D

2. A

OBJECTIVE 6.5

1. C

APPENDIX I

EQUATIONS		
OPTICS	**MECHANICS**	
$n_1 \sin\theta_1 = n_2 \sin\theta_2$	$v_{av} = \frac{\Delta d}{\Delta t}$	$F_E l_E = F_R l_R$
$M = \frac{h_i}{h_o}$	$a = \frac{\Delta v}{\Delta t}$	$E_g = mgh$
$\frac{h_i}{h_o} = -\frac{d_i}{d_o}$	$\Delta d = v_1 \Delta t + \frac{1}{2} a (\Delta t)^2$	$E_k = \frac{1}{2} m v^2$
$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f}$	$v_2 = v_1 + a\Delta t$	$F_E \Delta d_E = F_R \Delta d_R$
$P = \frac{1}{f}$	$v_2^2 = v_1^2 + 2a\Delta d$	$F = ma$
$P_t = P_1 + P_2 + ... + P_n$	$P = \frac{W}{\Delta t}$	$F_g = mg$
	$W = F \bullet \Delta d$	$F = kx$

PHYSICAL CONSTANTS		
SYMBOL	**QUANTITY**	**VALUE**
c	Speed of light in a vacuum	3.00×10^8 m/s
g	Acceleration due to gravity (earth)	9.8 m/s^2

Table of Trigonometric Ratios

Angle	sin	cos	Tan	Angle	sin	cos	tan
0°	0.0000	1.0000	0.0000	45°	0.7071	0.7071	1.0000
1°	0.0175	0.9998	0.0175	46°	0.7193	0.6947	1.0355
2°	0.0349	0.9994	0.0349	47°	0.7314	0.6820	1.0724
3°	0.0523	0.9986	0.0524	48°	0.7431	0.6691	1.1106
4°	0.0698	0.9976	0.0699	49°	0.7547	0.6561	1.1504
5°	0.0872	0.9962	0.0875	50°	0.7660	0.6428	1.1918
6°	0.1045	0.9945	0.1051	51°	0.7771	0.6293	1.2349
7°	0.1219	0.9925	0.1228	52°	0.7880	0.6157	1.2799
8°	0.1392	0.9903	0.1405	53°	0.7986	0.6018	1.3270
9°	0.1564	0.9877	0.1584	54°	0.8090	0.5878	1.3764
10°	0.1736	0.9848	0.1763	55°	0.8192	0.5736	1.4281
11°	0.1908	0.9816	0.1944	56°	0.8290	0.5592	1.4326
12°	0.2079	0.9781	0.2126	57°	0.8387	0.5446	1.5399
13°	0.2250	0.9744	0.2309	58°	0.8480	0.5299	1.6003
14°	0.2419	0.9703	0.2493	59°	0.8572	0.5150	1.6643
15°	0.2588	0.9659	0.2679	60°	0.8660	0.5000	1.7321
16°	0.2756	0.9613	0.2867	61°	0.8746	0.4848	1.8040
17°	0.2924	0.9563	0.3057	62°	0.8829	0.4695	1.8807
18°	0.3090	0.9511	0.3249	63°	0.8910	0.4540	1.9626
19°	0.3256	0.9455	0.3443	64°	0.8988	0.4384	2.0503
20°	0.3420	0.9397	0.3640	65°	0.9063	0.4226	2.1445
21°	0.3584	0.9336	0.3839	66°	0.9135	0.4067	2.2460
22°	0.3746	0.9272	0.4040	67°	0.9205	0.3907	2.3559
23°	0.3907	0.9205	0.4245	68°	0.9272	0.3746	2.4751
24°	0.4067	0.9135	0.4452	69°	0.9336	0.3584	2.6051
25°	0.4226	0.9063	0.4663	70°	0.9397	0.3420	2.7475
26°	0.4384	0.8988	0.4877	71°	0.9455	0.3256	2.9042
27°	0.4540	0.8910	0.5095	72°	0.9511	0.3090	3.0777
28°	0.4695	0.8829	0.5317	73°	0.9563	0.2924	3.2709
29°	0.4848	0.8746	0.5543	74°	0.9613	0.2756	3.4874
30°	0.5000	0.8660	0.5774	75°	0.9659	0.2588	3.7321
31°	0.5150	0.8572	0.6009	76°	0.9703	0.2419	4.0108
32°	0.5299	0.8480	0.6249	77°	0.9744	0.2250	4.3315
33°	0.5446	0.8387	0.6494	78°	0.9781	0.2079	4.7046
34°	0.5592	0.8290	0.6745	79°	0.9816	0.1908	5.1446
35°	0.5736	0.8192	0.7002	80°	0.9848	0.1736	5.6713
36°	0.5878	0.8090	0.7265	81°	0.9877	0.1564	6.3138
37°	0.6018	0.7986	0.7536	82°	0.9903	0.1392	7.1154
38°	0.6157	0.7880	0.7813	83°	0.9925	0.1219	8.1443
39°	0.6293	0.7771	0.8098	84°	0.9945	0.1045	9.5144
40°	0.6428	0.7660	0.8391	85°	0.9962	0.0872	11.4301
41°	0.6561	0.7547	0.8693	86°	0.9976	0.0698	14.3007
42°	0.6691	0.7431	0.9004	87°	0.9986	0.0523	19.0811
43°	0.6820	0.7314	0.9325	88°	0.9994	0.0349	28.6363
44°	0.6947	0.7193	0.9657	89°	0.9998	0.0175	57.2900
45°	0.7071	0.7071	1.000	90°	1.0000	0.0000	∞