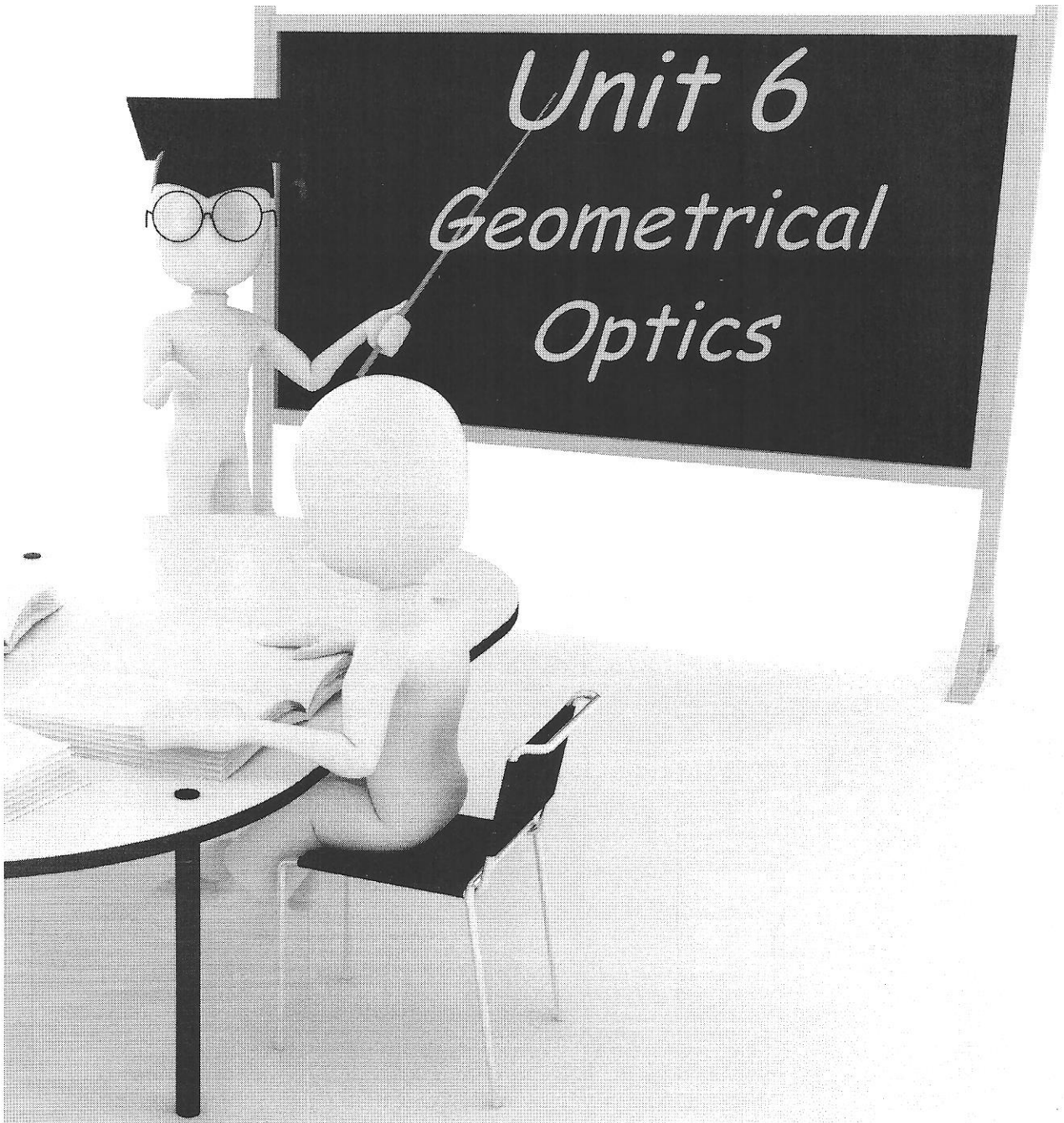


Stage 1 – Vocabulary

Geometrical Optics

collection [kə'lekʃ(ə)n] *n*	interpret [ɪn'tə:prɪt] *v*	paraboloidal [pə'ræbəlɔɪd(ə)l] *a*
cylinder ['sɪlɪndə] *n*	microscopic [ˌmaɪkrə'skɔpɪk] *a*	parallel ['pærəlel] *a*
effect [ɪ'fekt] *n*	mirage ['mɪrɑ:ʒ] / [mɪ'rɑ:ʒ] *n*	spherical ['sferɪk(ə)l] *a*
geometrical [dʒɪə'metrɪkəl] *a*	model ['mɔd(ə)l] *n*	trigonometric [ˌtrɪgənə'metrɪk] *a*

absorb [əb'sɔ:b] / [əb'zɔ:b] *v* поглощать, впитывать, абсорбировать
advantage [əd'vɑ:ntɪdʒ] *n* преимущество
aperture ['æpətʃə] / ['æpətjuə] *n* отверстие, щель; *опт.* апертура
appear [ə'pɪə] *v* казаться
arrow ['ærəu] *n* стрела, стрелка
assumption [ə'sʌmpʃ(ə)n] *n* предположение, допущение
beam [bi:m] *n* пучок
beyond [bɪ'jɔnd] *prep* за (пределами чего-л.)
bounce from / off [bauns] *v* отскакивать от
bound [baund] *v* ограничивать
coarse [kɔ:s] *a* грубый, шероховатый
common ['kɔmən] *a* 1) общий; 2) общеизвестный
concrete ['kɔnkri:t] *n* 1) конкретный; 2) бетонный
cone [kəun] *n* конус;
  cone of rays – *физ.* пучок лучей
constitute ['kɔnstɪtju:t] *v* основывать, составлять
continuous [kən'tɪnjuəs] *a* сплошной
converge [kən 'və:dʒ] *v* сходиться, сводиться в одну точку
deflect [dɪ'flekt] *v* преломляться
deviate ['di:vɪeɪt] *v* отклоняться, уклоняться
device [dɪ'vaɪs] *n* прибор, устройство, установка
diffuse [dɪ'fju:s] *a* диффузный, рассеянный
diminish [dɪ'mɪnɪʃ] *v* уменьшать
distort [dɪs'tɔ:t] *v* искажать, искривлять
diverge [daɪ'və:dʒ] *v* расходиться
dot [dɔt] *n* точка;
  a dotted line – пунктирная линия
erect [ɪ'rekt] *a* прямой
farther ['fɑ:ðə] *adv* дальше (*сравн. ст. от* far)
figure ['fɪgə] *n* иллюстрация, рисунок
ground glass ['graundglɑ:s] *n* матовое стекло
homogeneous [hɔməu'dʒi:nɪəs] *a* однородный
image ['ɪmɪdʒ] *n* образ, изображение, отражение (в зеркале)
imaginary [ɪ'mædʒɪnərɪ] *a* воображаемый, мнимый
incident ['ɪnsɪdənt] *a* падающий
indefinitely [ɪn'def(ə)nətlɪ] *a* неограниченно; бесконечно, беспредельно
interface ['ɪntəfeɪs] *n* граница /поверхность/ между двумя материалами /средами/
intersect [ˌɪntə'sekt] *v* пересекаться
introduction [ˌɪntrə'dʌkʃ(ə)n] *n* введение (*в научную дисциплину*)
invert [ɪn'və:t] **1)** *a* обратный;
  2) *v* переворачивать, перевертывать
irregularity [ɪˌregju'lærətɪ] *n* неровность
language ['læŋgwɪdʒ] *n* язык; речь
lateral ['lætərəl] *n* боковой, горизонтальный
lens [lenz] *n* линза, оптическое стекло;
  converging lens – собирающая линза;
  diverging lens – рассеивающая линза
magnify ['mægnɪfaɪ] *n* увеличивать
medium ['mi:djəm] *n* (*pl* media) среда
mirror ['mɪrə] *n* зеркало
normal ['nɔ:məl] *n* перпендикуляр, нормаль
obliquely [ə'bli:klɪ] *adv* под углом, косо
opaque [əu'peɪk] *a* непрозрачный
pencil ['pensl] *n опт.* пучок
previous ['pri:vjəs] *a* предыдущий
propagation [ˌprɔpə'geɪʃ(ə)n] *n* распространение
pupil ['pju:pl] *n* зрачок
quantitative ['kwɔntɪtətɪv] *a* количественный
ray [reɪ] *n* луч
reflection [rɪ'flekʃ(ə)n] *n* отражение
refraction [rɪ'frækʃ(ə)n] *n* преломление;
  refractive index – показатель /коэффициент/ преломления
regular ['regjulə] *n* правильный;
  regular reflection – зеркальное отражение
result from [rɪ'zʌlt] *v* следовать, проистекать из; происходить в результате (чего-л.)

reverse [rɪ'və:s] *v* перевертывать, поворачивать(ся) в противоположном направлении
rough [rʌf] *a* неровный, шершавый
scatter ['skætə] *v* рассеивать
seem [si:m] *v* казаться
silver ['sɪlvə] *a* серебряный
slender ['slendə] *a* тонкий, слабый
smooth [smu:θ] *a* гладкий, ровный
speculum ['spekjuləm] *n* (*pl* -la) 1) отражатель, рефлектор; 2) зеркало
straight [streɪt] *a* прямой
strike [straɪk] *v* (struck) ударять(ся)
tiny ['taɪnɪ] *a* крошечный
transparent [træns'pær(ə)nt] *a* прозрачный
ultimate ['ʌltɪmɪt] *a* 1) предельный; окончательный, конечный; 2) основной
uneven [ʌn'i:vn] *a* неровный, шероховатый
vice versa ['vaɪsɪ'və:sə] *adv* наоборот
virtual ['və:tjuəl] *n* фактический;
virtual image – мнимое изображение

as well – также
to get right – правильно понимать
to give attention (to) – уделять внимание, обращать внимание (на)
to give rise to – давать начало; приводить к; стать причиной
in any / either case – в любом случае, во всяком случае, при любых обстоятельствах; как бы там ни было; по крайней мере
unless otherwise stated /mentioned, specified/ – кроме случаев, оговоренных особо; если не оговорено особо

abbreviation:
viz. (Lat. – *videlicet*) = **namely** – а именно

Task I. Pay attention to …

I. Pay attention to the pronunciation of the following words.

sphere [sfɪə] – spherical ['sferɪk(ə)l], image ['ɪmɪdʒ] – imaginary [ɪ'mædʒɪnərɪ]

II. Pay attention to the following derivatives and translate them.

assume → assumption;
definite → indefinite → indefinitely;
direct → direction;
even → uneven;
face → interface;
form → formation;
geometry → geometric(al);
incident → incidence;
introduce → introduction;
inverse → inversion;
microscope → microscopic(al);
optics → optical;
propagate → propagation;
quantity → quantitative → quantitatively;
reflect → reflection;
refractive ← **refract** → refraction;
regular → irregular → irregularity;
↓ ↓
regularly irregularly
relate → relation;
simple → simplicity;
speculum → specular

Suffixes:
-ar *n* → *a*
-ation/-(t)ion *v* → *n*
-ative *n* → *a*
-ence *a* → *n*
-ic(al) *n* → *a*
-ly *a* → *adv*
-ity *a* → *n*

Prefixes:
inter- 'between / among' 'from one to another'
in- *'the opposite of' / 'not'*
ir- *'the opposite of' / 'not'*
un- *'the opposite of' / 'not'*

A fuller list of affixes is given on pp 9-13.

*III. Pay attention to '**noun** + **noun**' combinations. Read and translate them.*
light intensity, a light ray, a light beam, a light model, a wave model, a ray model, a particle model, a ground glass surface, a water surface, image formation, a New Year tree ball

IV. Pay attention to the singular and plural of the following nouns.
a) index – ind**ices** / index**es**, medium – medi**a** / mediums, phenomen**on** – phenomen**a**, specul**um** – specul**a**
b) 'len**s**' *is the singular*, 'len**ses**' *is its plural*

A. Choose the correct form(s) of the noun.
1. (*A speculum / Specula / Speculums / Speculas*) provides the most common example for regular reflection.
2. (*A speculum / Specula / Speculums / Speculas*) have a high reflection factor.
3. Convex (*lens / lenses*) are converging ones.
4. A concave (*lens / lenses*) is a diverging lens.
5. The speed of light rays changes when they pass through various (*medium / media / mediums*).
6. Refraction takes place when a ray of light passes from one (*medium / media / mediums*) to another.
7. Refractive (*index / indices / indexes*) is a property of a material (*medium / media / mediums*).
8. (*Index / Indices / Indexes*) of names and figures are contained in the dictionary.
9. Transparent (*medium / media / mediums*) surfaces can produce regular reflection.
10. Optical (*phenomenon / phenomena / phenomenas / phenomenons*) like reflection and refraction are described by the ray model of light.
11. Optical (*phenomenon / phenomena / phenomenas / phenomenons*) like reflection from a curved (*speculum / specula / speculums / speculas*) is described by the ray model of light.

B. Underline the correct word(s).
1. (*This / these*) lens (*converge / converges*) a beam of light. (*They are / It is*) called convex.
2. Specula (*produce / produces*) regular reflection.
3. We can see the image in a speculum as light rays are regularly reflected from (*it / them*).
4. (*This / These*) light phenomenon (*is / are*) interpreted in terms of waves.
5. (*One / Many*) natural phenomena (*result / results*) from refraction.
6. Material media (*have / has*) an influence on the speed of a light ray through which it passes.

V. Pay attention to the following international words. They are often called 'false friends of a translator' as they can be translated in different ways.

concrete ['kɔnkri:t] *n* 1) конкретный; 2) бетонный

figure ['fɪgə] *n* 1) фигура; внешний вид; облик, образ; 2) личность, деятель, фигура; 3) изображение, картина; статуя; 4) иллюстрация, рисунок (*в книге*); диаграмма, чертеж; 5) *геом.* фигура, тело; 6) цифра; *pl* (цифровые) данные; 7) *pl* арифметика

index ['ɪndeks] *n* (*pl* indices) 1) индекс, указатель; 2) стрелка (*на приборах*); 3) алфавитный указатель, каталог; 4) *мат.* показатель степени, коэффициент; **refractive index** – показатель /коэффициент/ преломления

medium ['mi:djəm] **1)** *n* (*pl* media / mediums) 1) средство, способ; 2) середина; промежуточная ступень, стадия; 3) обстановка, условия (*жизни*), окружение, окружающая реальность, среда; 4) *физ.* среда; **refractive medium** – преломляющая среда;5) агент, посредник; 6) медиум (*в спиритизме*)
2) *a* 1) средний, промежуточный; **medium wave** – (радио) волна средней длины (*от 100 до 800 м*); 2) умеренный

model ['mɔd(ə)l] *n* 1) модель, макет (*уменьшенная копия чего-л.*); шаблон; 2) модель (*идеализированное или упрощенное описание чего-л.*); 3) образец, эталон; пример

normal ['nɔ:məl] **1)** *a* 1) нормальный, обыкновенный; обычный; 2) средний, среднеарифметический; 3) *геом.* перпендикулярный
2) *n* 1) нормальное состояние; 2) *геом.* нормаль, перпендикуляр

Translate the following sentences. Pay special attention to the words in bold.

1. Let us illustrate the phenomenon of reflection with a **concrete** example.
2. A **concrete** wall produces diffuse reflection.
3. Evidently a **figure** convex relative to its boundary is convex.
4. **Figure** 1 demonstrates rays of light leaving a source.
5. The **figures** represented in Table 1 appear to be relatively large.
6. The dictionary contains **indices** of names and **figures**.
7. In the case of electromagnetic radiation, especially light, it is usual to give values of absolute refractive **index** of a **medium**.
8. Light travels through the **medium** of air.
9. A **medium** frequency corresponds to a wavelength in the range 1000 m to 100 m.
10. I consider your journal to be one of the best possible **media** for papers dealing with geometrical optics.
11. Light from an incandescent gas under **medium** pressure produces a line spectrum.
12. Today physics deals with two **models** of light to describe optical phenomena: wave and particle ones.
13. A **normal** mirror provides the most common **model** for regular reflection.
14. Refraction occurs when a ray of light passes from a less dense to a denser **medium**. If the direction of the ray is **normal** to the surface, it passes through without change of direction. If the direction of the ray is at an angle to the **normal** then the ray will be deflected towards the **normal**.
15. We do not observe diffraction of light under **normal** condition, *i.e.* as light passes through windows, doors, *etc*.

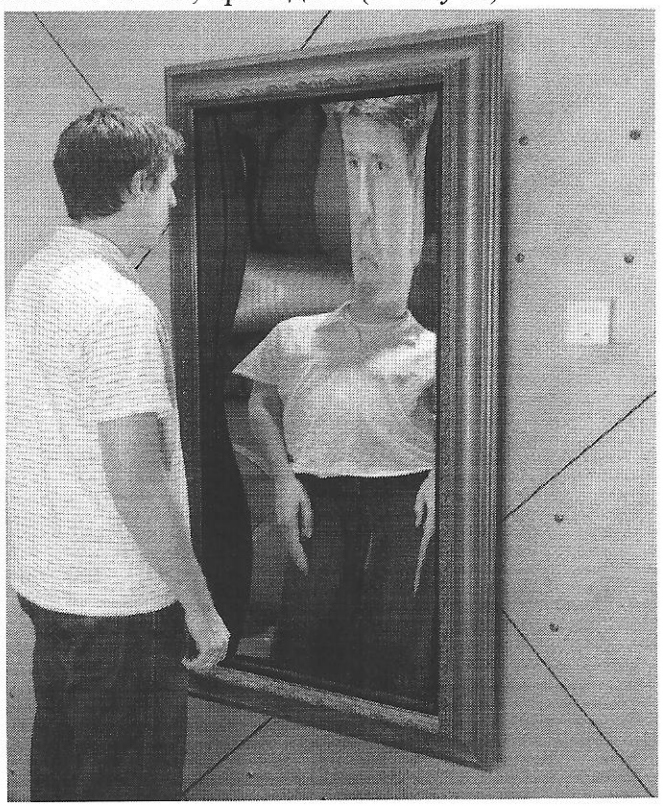
VI. Pay attention to the phrasal verbs.

account [ə'kaunt] *v* рассматривать как; считать за
account for – объяснять (что-л.); являться причиной (чего-л.), отвечать (за)

result [rɪ'zʌlt] **1)** *n* 1) результат, исход; **2)** *v*:
result from – происходить в результате (*чего-л.*); следовать, проистекать из
result in – кончаться *чем-л.*, иметь результатом *что-л.*, приводить (к *чему-л.*)

Underline the correct variant.

1. Light (*is accounted / is accounted for*) propagating in the form of rays in geometrical optics.
2. Many natural phenomena result (*from / in*) refraction.
3. Reflection of light from the surface of a mirror results (*from / in*) image formation.
4. Geometrical optics (*accounts / accounts for*) the phenomenon of reflection from curved mirrors resulting (*from / in*) formation of the distorted images you laugh at.



VII. Pay attention to the following easily confused words.

a) **cause** [kɔ:z] *n* причина, основание, повод
coarse [kɔ:s] *a* 1) грубый; 2) шероховатый
course [kɔ:s] *n* 1) курс, направление;
2) курс (*лекций, обучения*)

b) **because** [bɪ'kɔz] *cj* потому что, так как, поскольку
because of [bɪ'kɔzəv] *prep* из-за, вследствие

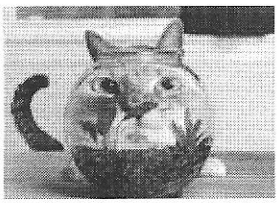
c) **same** [seɪm] *pron* один и тот же; одинаковый
some [sʌm] *pron* несколько, некоторый

d) **compare** [kəm'pɛə] *v* сравнивать; выявлять сходство
contrast [kən'trɑ:st] *v* сопоставлять; выявлять различие

e) **next** [nekst] *a* следующий за; ближайший, соседний
following ['fɔləuɪŋ] *a* (по)следующий

f) **high** [haɪ] *adv* высоко (*о высоте*)
highly ['haɪlɪ] *adv* высоко (*о степени*), весьма

g) **optic** ['ɔptɪk] *a* глазной, зрительный
optical ['ɔptɪk(ə)l] *a* оптический, зрительный



*Refraction is the **cause** of various funny **optical** phenomena.*

Choose the correct word to complete the sentences.

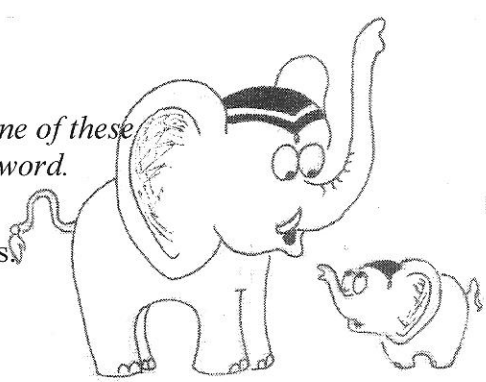
1. To describe (*optic / optical*) phenomena physics deals with the (*following / next*) models of light: wave and particle ones. We are going to (*compare / contrast*) these different ways of interpreting one and (*some / the same*) reality. The former (*compares / contrasts*) light with waves. The particle model (*compares / contrasts*) light with photons or particles. The (*following / next*) problem under discussion is to account for (*some / the same*) light phenomena in terms of geometrical optics which (*compares / contrasts*) light with rays.
2. The (*cause / coarse / course*) of incandescence is high temperature.
3. Reflection and refraction of light are dealt with in the (*cause / coarse / course*) of ray optics.
4. When a beam of parallel rays strikes a (*high / highly*) polished surface it is reflected as a beam of parallel rays. When a beam of parallel rays strikes (*cause / coarse / course*) surface it is reflected in all different directions (*because / because of*) the microscopic irregularities of the surface.
5. Light rays bounce off a concrete wall in all directions (*because / because of*) its surface is uneven and it provides (*same / some*) tiny reflecting surfaces.
6. We can see the image in a mirror (*because / because of*) regular reflection.
7. We can see the image in a mirror (*because / because of*) light rays are regularly reflected from it.
8. (*Some / The same*) rays of light from (*some / the same*) point source are not parallel to each other.
9. We can observe various (*optic / optical*) illusions (*because / because of*) refraction of light.

Fun with Words

MNEMONIC DEVICES
МНЕМОНИЧЕСКИЕ ПРИЕМЫ

Is it difficult for you to spell the word BECAUSE*? Remember one of these phrases or both. The initial letters of the words spell out this word.*

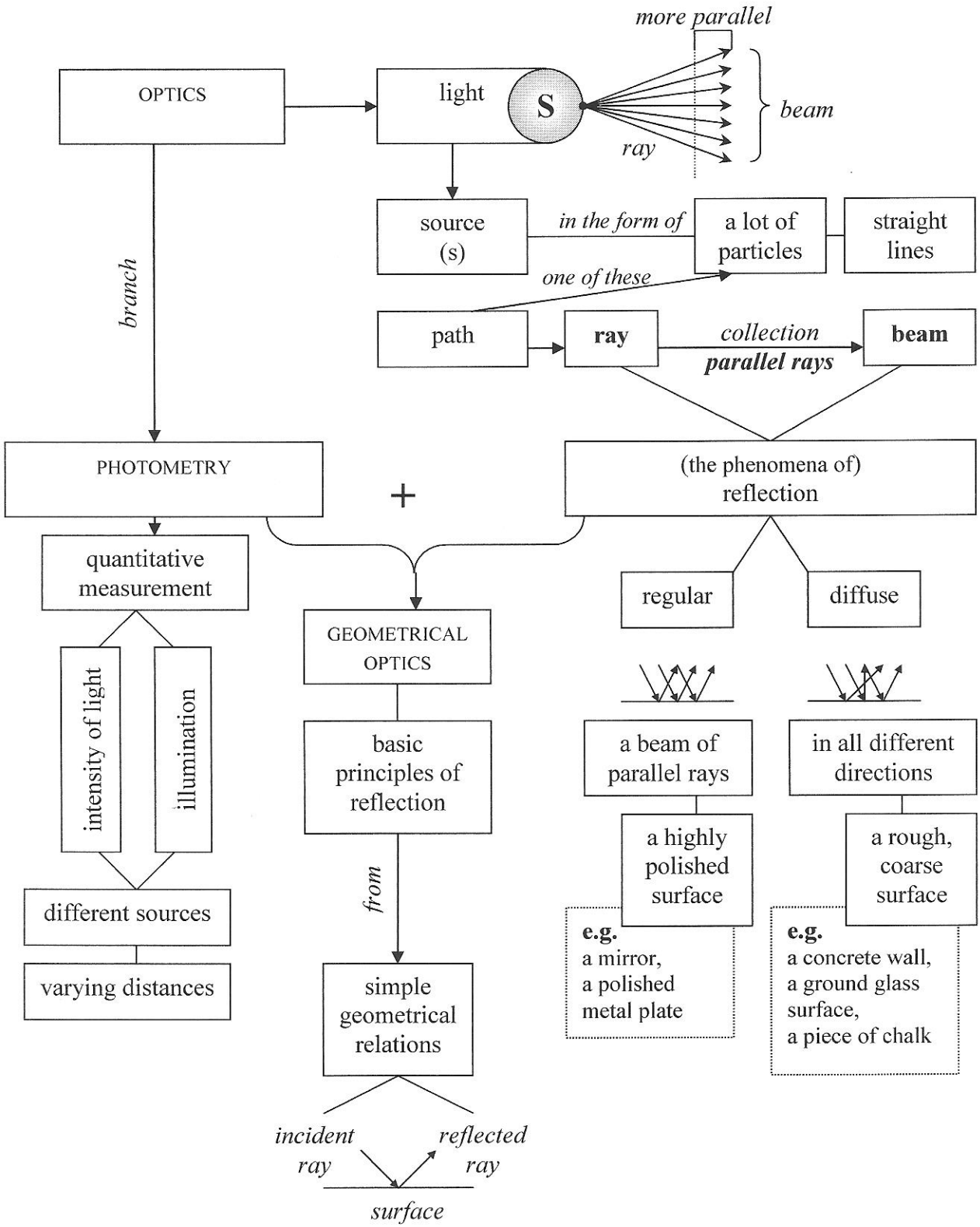
BECAUSE
Big **E**lephants **C**an **A**lways **U**nderstand **S**mall **E**lephants.
Big **E**lephants **C**an't **A**lways **U**se **S**mall **E**ntrance.



A fuller list of spelling mnemonics is given on page 16.

Stage 2 – Schemes

SCHEME 6



Task II. Use the scheme given on the left-hand page as a prompt to do the following exercises.

SCHEME 6

I. Choose the right variant:

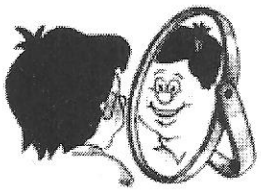
1. (*Kinematics / Dynamics/ Optics*) is the science studying light.
2. It is convenient to think that light leaves a source in the form of a lot of particles travelling in (*straight / curved*) lines.
3. The path followed by one of these particles is called a (*beam / ray*) of light.
4. The farther the rays of light get from the source the (*less / more*) parallel they seem.
5. A collection of (*parallel / non-parallel*) rays of light is called a beam of light.
6. One of the optical phenomena which can be studied by using rays and beams is (*diffraction / reflection*).
7. Photometry together with the (*reflection / interference*) of light constitute an introduction to (*wave / geometrical*) optics.
8. Photometry is the branch of (*mechanics / optics*) that involves (*quantitative / qualitative*) measurement of the intensity of light and the illumination provided by different sources on surfaces at (*unvarying / varying*) distances from the source.
9. The basic principles of reflection are derived from simple geometrical relations between incident and (*refracted / reflected*) rays.
10. The ray which (*strikes / leaves*) the surface is an incident ray.
11. The ray which (*strikes / leaves*) the surface is a reflected ray.
12. Reflection can be (*normal / regular*) and (*diffuse / abnormal*).
13. When a beam of parallel rays is reflected as a beam of (*non-parallel / parallel*) rays we have regular reflection.
14. When a beam of parallel rays is reflected in all different directions we have (*diffuse / regular*) reflection.
15. Regular reflection occurs when light is reflected from a (highly polished / rough) surface.
16. (*Diffuse / Regular*) reflection occurs when light is reflected from a coarse surface.
17. A mirror or a metal plate produces (*diffuse / regular*) reflection.
18. A concrete wall, a ground glass surface and a piece of chalk produce (*diffuse / regular*) reflection.

II. Answer the following questions:

1. What does optics study?
2. What is a ray /beam/ of light?
3. Which optical phenomena can be studied by using rays?
4. What does photometry involve?
5. What constitutes an introduction to geometrical optics?
6. What is an incident /a reflected/ ray?
7. What is regular /diffuse/ reflection?
8. What produces regular reflection?
9. When does diffuse reflection occur?

III. Discuss photometry, geometrical optics, and phenomena studied by these branches.

Stage 3 – Text



Geometrical Optics

Each branch of optics studies light in terms of certain properties and concepts. In the previous paper we discussed photometry. As we have already pointed out it includes quantitative measuring luminous fluxes and quantities related to them, *viz.*, the intensity of light and the illumination provided by different sources on surfaces at varying distances from the source. Photometry together with the reflection of light constitute an introduction to geometrical optics. It is also often called ray optics.

Today physics deals with two models of light to describe optical phenomena: wave and particle ones. The latter assumes light to leave a source in the form of an indefinitely large number of imaginary particles moving at high speed. According to the former light phenomena are interpreted in terms of waves. The length of light waves perceived by the human eyes being very small, the propagation of light can be considered without giving attention to its wave nature. Thus, ray, or geometrical, optics compares the propagation of light with the directed straight lines called rays in geometry and describes laws of optics using the terms of geometry. The advantage of the ray model is its simplicity. It should be noted that the ray model is not the ultimate truth about light, but in any case science does deal with models of reality, not the ultimate nature of reality.

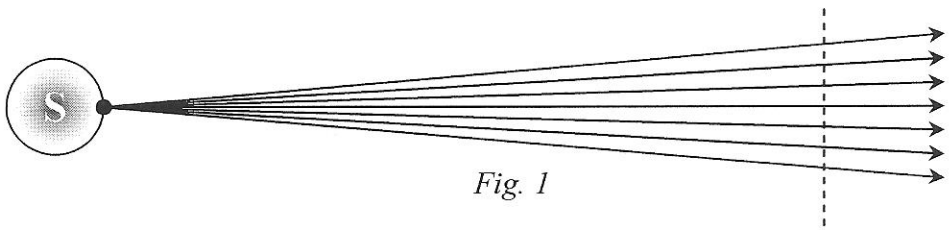


Fig. 1

In Fig. 1 the arrows represent rays of light leaving S (a source). Rays of light from the same point source are not parallel to each other, since they must intersect at their common source. However, the farther the rays of light get from the source, the more parallel they seem (*e.g.* beyond the dotted line in the figure). A collection of (almost) parallel light rays is called a beam of light. The ray or beam of light which strikes the surface is called an incident ray or beam. The ray or beam leaving the surface is known to be a reflected ray or beam. The fundamental principles and equations of reflection and refraction are derived from the assumption of simple geometric (and trigonometric) relations between incident and reflected, and incident and refracted light rays.

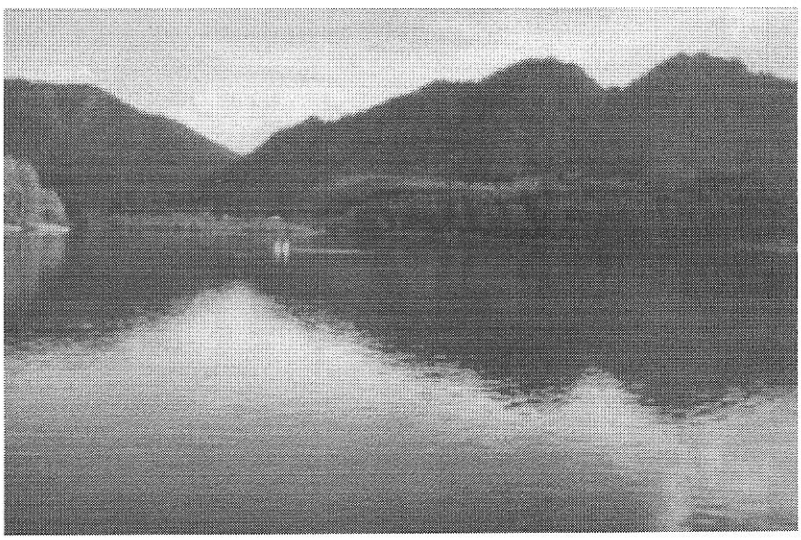


Fig. 2
The reflection of mountains from the surface of water

Fig. 3
It is geometrical optics that accounts for the distorted forms produced by New Year tree balls or by curved mirrors we laugh at.

Reflection of light may be regular and diffuse depending on the nature of the surface. If a reflecting surface is very smooth or highly polished the reflection of light that occurs is called regular or specular. In this case a beam of parallel rays is reflected as a beam of parallel rays. A mirror provides the most common model for regular reflection. The light reflected to your eyes from a polished silver plate also an example of regular reflection. It is possible for reflection to occur from the surface of transparent media, such as water or glass. We can see the image in a speculum or water surface because of regular reflection. By the way, as far as the phenomena of reflection from plane and curved mirrors or very smooth surfaces are concerned, they are accounted for by geometrical optics, *e.g.* the distorted forms produced by curved mirrors, by New Year tree balls, *etc.*

As noted above, light can be diffusely reflected. When a beam of parallel rays strikes a rough, coarse surface such as a concrete wall, a ground glass surface, a piece of chalk, *etc.*, it bounces off in all different directions due to the microscopic irregularities of the surface. Thus, an image is not formed. This is called diffuse or irregular reflection.

Not all the radiation is reflected; some may be refracted. Refraction is the change in the direction of a light ray. It takes place when a ray of light passes from one medium to another. *e.g.* from air to water. Refraction can be found all around us. If you have ever seen a seemingly bent spoon in a glass of water, you have seen the effect of refraction. Many natural phenomena result from refraction as well. It also helps us understand image formation by lenses and the eye.
(Do exercise II to complete this paragraph with some details.)

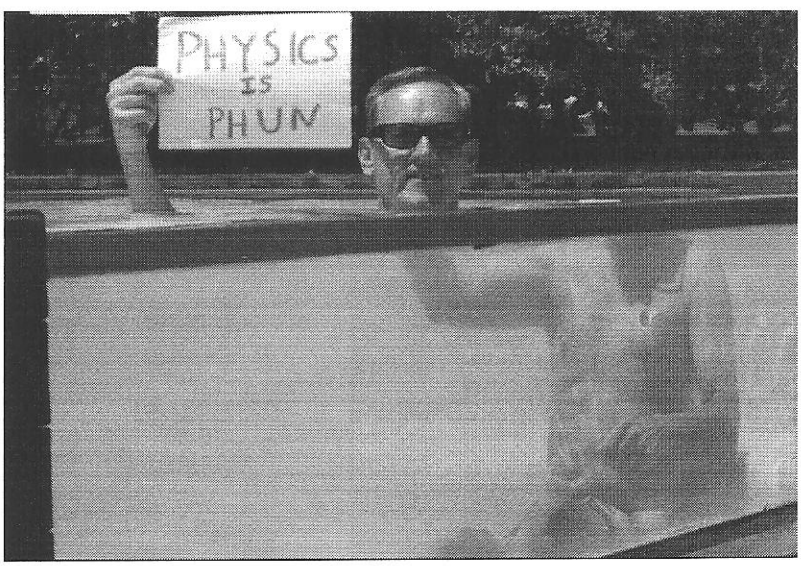


Fig. 4
This optical effect is due to refraction of light.

Task III. Read the text and then do the following exercises.

I. In the text, find the English equivalents for the words and phrases below:

- на основании определенных свойств
- вторая (из двух названных моделей) предполагает / допускает, что
- в виде
- бесконечно большое число
- согласно первой (из двух названных моделей)
- пренебрегая его волновой природой
- истина в последней инстанции
- в любом случае
- наука действительно рассматривает
- истинная природа
- за пределами пунктирной линии
- выводятся из допущения
- в зависимости от
- тщательно полированная (поверхность)
- самый общеизвестный пример
- благодаря / вследствие / из-за *(find 2 equivalents)*
- между прочим

II. Read the definition given in the box and then complete the last paragraph of the text with some details.

Not all the radiation is reflected; some may be refracted. Refraction is the change in the direction of a light ray *due to the* ... ... It takes place when a ray of light passes ... from one ... medium to another *medium which has a* ... ... , *e.g.* ... ... Refraction can be found all around us. If you have ever seen a seemingly broken spoon in a glass of water, you have seen the effect of refraction. Many natural phenomena *like* ..., ... *etc.*, result from refraction as well. It also helps us understand image formation by lenses and the ... eye *and the* ... ...

> ***Refraction*** *is the change in direction of light rays resulting from the change in their speed as they pass obliquely from one transparent medium to another, that of a different density, e.g. from air to water. Numerous natural phenomena are produced by refraction. Thus, the spoon standing in water seems broken at the surface where the air and water meet. It throws light on the working of the human eye and the defects of vision. It also causes the optical phenomena of rainbows, mirages, etc.*

III. Create as many sentences as possible:
e.g. Regular reflection occurs when the *surface is smooth and highly polished.*

• Regular reflection • Specular reflection • Diffuse reflection • Irregular reflection • Refraction • An image	• occurs • takes place • originates • does not occur • does not take place • does not originate • is (not) formed • is (not) produced	• when • as • if • in case • as long as • provided (that) • providing (that) • on the condition (that)	• a beam of parallel rays is reflected as a beam of parallel rays. • a beam of parallel rays is reflected in all different directions. • light is reflected from a smooth and highly polished surface. • light is reflected from a rough and coarse surface. • light is reflected from a mirror. • light is reflected from a concrete wall, a ground glass surface, *etc.* • the surface is rough and coarse. • the surface is smooth and highly polished. • a ray of light passes from one medium to another. • a ray of light passes from air to water.
We have	• regular reflection • specular reflection • diffuse reflection • irregular reflection • refraction		
• Light • A beam of light • A ray of light	• is regularly reflected • is specularly reflected • is diffusely reflected • is irregularly reflected • is refracted		

IV. Fill in the gaps with the correct preposition.

1. The present paper is concerned … the phenomena of light.
2. The light intensity and the illumination provided … different sources … surfaces … varying distances … the source are dealt … in photometry.
3. According … the wave theory light phenomena are interpreted … terms … waves.
4. Since the length … light waves perceived … the human eyes is very small, the propagation … light can be considered … giving attention … its wave nature
5. Geometrical optics compares the light propagation … rays.
6. This comparison gave rise … the name … the branch.
7. The ray model accounts … the images produced … curved mirrors.
8. Reflection of light may be regular and diffuse depending … the surface nature.
9. We can see the image in a mirror because … regular reflection.
10. Refraction is the change … the direction of a light ray due … the change … its speed.
11. Refraction occurs when a light ray passes … one medium … another.
12. Image formation … lenses and the eye results … refraction.

V. Use suitable forms of the words from the box instead of the underlined ones.

1. Photometry includes quantitative measuring luminous fluxes and quantities related to them.
2. The corpuscular theory assumes light to leave a source in the form of an indefinitely large number of imaginary particles.
3. The propagation of light can be considered without giving attention to its wave nature.
4. The language of geometry used to formulate the laws of optics gave rise to the name of the branch.
5. The branch is often called ray optics.
6. When light rays get father from their source, they seem to be more parallel to each other.
7. Reflection of light may be regular and diffuse.
8. Diffuse reflection takes place when light is reflected from a rough surface, for example from a concrete wall.
9. Geometrical optics accounts for the phenomena of reflection from plane and curved mirrors.
10. Not all the rays are reflected, some of them are refracted.
11. Refraction is the change in the direction of a light ray due to the change in its speed.

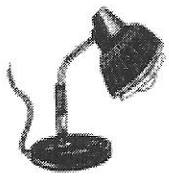
a) instance
b) ray
c) speculum
d) irregular
e) numerical
f) uneven
g) specular
h) to appear
i) to cause
j) to deflect
k) to explain
l) to involve
m) to occur
n) to pay
o) to suppose
p) frequently
q) because of
r) as

VI. Change the following sentences from active to passive.

1. Today we deal with two models of light in physics.
2. The wave theory explaines light phenomena in terms of waves.
3. In ray optics we examine the propagation of light without giving attention to its wave nature.
4. In geometrical optics we neglect the wave nature of light.
5. We compare the propagation of light with the directed straight lines called rays in geometry.
6. Geometrical optics uses the language of geometry to formulate laws.
7. Science does not always consider the ultimate nature of reality. We often refer to the models of reality in science.
8. Ray optics accounts for the phenomena of reflection and refraction.
9. A mirror provides the most common model for regular reflection.
10. The surface of transparent media, such as water or glass, can produce an image.
11. A concrete wall or a piece of chalk produces diffuse reflection.
12. A coarse surface does not form an image, because it diffusely reflects light rays.

IN OTHER WORDS

- The wave model considers light in terms of waves.
  The wave model considers light to propagate in the form of waves.
  According to the wave model light propagates in the form of waves.
  The wave model compares (the propagation of) light with waves.
- The light beam that is reflected from a rough surface is an example of diffuse reflection.
  The light beam reflected from a rough surface is an example of diffuse reflection.
- The beam of light which strikes the surface is called an incident one.
  The beam of light striking the surface is (called) an incident one.
  The beam of light striking the surface is known as an incident one.
  The beam of light striking the surface is known to be an incident one.
  We know the beam of light striking the surface to be an incident one.
- The particle model assumes that light leaves a source in the form of a great number of particles.
  The particle model assumes light to leave a source in the form of a great number of particles.
  Light is assumed (by the particle model) to leave a source in the form of great number of particles.
  The particle model assumes light leaving a source in the form of great number of particles.
  Light is assumed (by the particle model) leaving a source in the form of great number of particles.



VII. Rewrite each sentence so that your sentence has a similar meaning to the given one. Write as many sentences as possible.

1. The particle model considers light in terms of particles.
2. According to the ray model light propagates in the form of rays.
3. Rays of light leaving the same point source are not parallel to each other.
4. The distorted forms which are produced by curved mirrors are accounted for by ray optics.
5. The surface producing regular reflection must be smooth or highly polished.
6. The ray of light that passes from one medium to another is refracted.
7. The reflection of light taking place when a reflecting surface is coarse is called irregular.
8. The ray of light that bounces off the surface is known as a reflected one.
9. The particle model supposes that particles travel at high speed.
10. We assume that an uneven surface reflects light rays diffusely.
11. One considers that specula provide the most common example for regular reflection.

VIII. Rewrite the sentences using emphatic constructions, as in the example, and translate them.

A) ***'it is / was ... that / which / who' – именно, только***

Simplicity is the advantage of the ray model.
It is simplicity ***that / which*** is the advantage of the ray model. ***Именно*** *простота является преимуществом лучевой модели.*

1. Geometrical optics explains funny images produced by distorting mirrors.
2. Ray optics accounted for these light phenomena.
3. Mirrors provide the most common model for regular reflection.
4. The language of geometry used to formulate laws of optics gave rise to the name 'geometrical optics'.
5. The rays of light striking the surface are called incident rays.
6. Refraction causes a spoon to seem broken in a glass of water.

The student makes ...
It is *the student* ***that / who*** *makes ...*
Students make ...
It is *students* ***that / who*** *make ...*
Students made ...
It was *students* ***that / who*** *made ...*
Science makes ...
It is *science* ***that / which*** *makes ...*
Science made ...
It was *science* ***that / which*** *made ...*

B) ***'do / does / did + V' – действительно, на самом деле, все же, несомненно, фактически, ведь***

V → do V
V_S → does V
V_2 → did V

Science deals with models of reality, not ...
Science ***does deal with*** *models of reality, not ...*
Наука ***действительно*** *рассматривает модели реальности, а не ...*

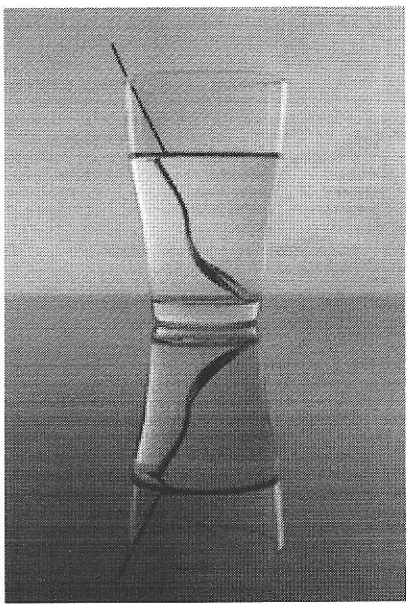
7. Reflection occurs from the surface of transparent media, such as water or glass.
8. We see the image in a mirror because of regular reflection.
9. Geometrical optics uses the language of geometry to formulate laws.
10. The comparison light with rays gave rise to the name 'ray optics'.
11. They interpreted these phenomena in terms of waves.

IX. Underline the right variant and then match each term with its definition.

1. Reflection 2. Regular / Specular reflection 3. Diffuse / Irregular reflection 4. Refraction	a) that from a (*smooth / rough*) surface, in which a single beam of light is divided into many reflected rays going in many directions; b) that from a (*smooth / rough*) surface, in which the light ray leaves at the same angle at which it has come in; c) the deflection of light rays on passing (*directly / obliquely*) from one (*transparent / opaque*) medium into another one in which its speed is (*the same / different*); d) the return of light rays from a surface that it strikes into the medium through which it has travelled in such a way that the angle at which a given ray is returned (*is / is not*) equal to the angle at which it strikes the surface.

X. Ask your friends

1) what photometry is concerned with;
2) what models of light physics deals with today;
3) if the corpuscular theory interprets light in terms of waves;
4) what geometrical optics is;
5) what phenomena are under study in ray optics;
6) what a ray /beam/ of light is;
7) whether a beam of light striking the surface is an incident or a reflected one;
8) what regular reflection is;
9) what surfaces are known to produce specular reflection;
10) if ray optics accounts for the reflection from curved mirrors;
11) when we have a diffuse reflection;
12) whether all the radiation is reflected;
13) what phenomena of light you can observe in the picture.



XI. Annotate scheme 6 using the text "Geometrical Optics" and then describe the scheme in your own words. While describing, make use of

1) the following grammar structures:
   a) emphatic constructions ***'it is / was ... that / which / who'; 'do / does / did V';***
   b) complex object ***'... consider/considers ... to V/ V_{ing} / V_2';***
   c) complex subject ***'... is/are known to V/ V_{ing} / V_2';***
2) the expressions given on pages 167 – 168.

XII. Write an abstract (a summary) of the text. The instructions for writing an abstract are given on pages 173 – 175.

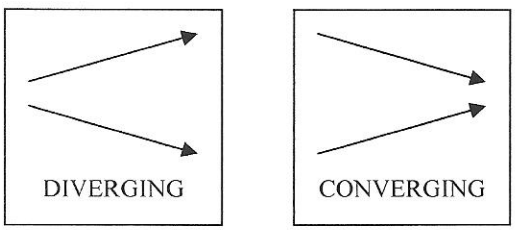
Stage 4 – Definitions *From "Longman Dictionary of Scientific Usage"*

beam A collection of *pencils* (↓) of rays forms a beam of light. It can be composed of parallel rays, *divergent* (↓) rays, or *convergent* (↓) rays. A beam of any electromagnetic radiation is similar to a beam of light.

pencil A slender cylinder or cone of rays which passes through an optical system; the term only describes light rays. A pencil of rays is limited in diameter by an aperture. The chief ray of a pencil is the central ray, and it passes through the centre of the aperture and the centre of the pupil of the eye. Pencils of rays can be *diverging* (↓) from a point or *converging* (↓) to a point, or can consist of parallel rays.

diverge 1. (Of a *beam* (↑) of radiation) to grow wider the further it travels, *e.g.* a beam of light diverges after passing through *a concave lens* (↓). **2.** To cause to diverge, *e.g.* a concave lens diverges a beam of light. – ***divergent, diverging*** *(adj.)*

converge 1. (Of a *beam* (↑) of radiation) to become narrower the further it travels, *e.g.* a beam of light converges after passing through *a convex lens* (↓). **2.** To cause to converge, *e.g.* a convex lens converges a beam of light. – ***convergent, converging*** *(adj.)*



diverging 1. Describes a beam of radiation, *e.g.* light of steadily increasing diameter, which appears to be directed away from a point. **2.** Describes a lens or mirror which produces this effect. A diverging lens is *a concave lens* (↓); a diverging mirror is *a convex mirror* (↓). – ***diverge*** *(v.),* ***divergent*** *(adj.)*

converging 1. Describes a beam of radiation, *e.g.* light of steadily decreasing diameter, which appears to be directed to a point. **2.** Describes a lens or mirror which produces this effect. A converging lens is *a convex lens* (↓); a converging mirror is *a concave mirror* (↓). – ***converge*** *(v.),* ***divergent*** *(adj.)*

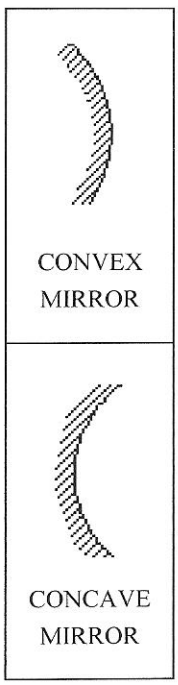
image A copy, either solid or optical, of an object. In optics, an image is a copy produced by a *mirror* (↓), or *lens* (↓), of an object placed in front of it. It may be real or virtual; the same size, diminished, or magnified; erect or inverted.

mirror An optical device for producing reflection. The surface may be plane or spherical. Other surfaces of revolution can be used, such as paraboloidal and elliptical surfaces. A mirror must have a high reflection factor. The reflection must be *regular* (↓) and specular, *e.g.* a piece of glass silvered on one side, or a polished sheet of silver, form a mirror.

plane mirror The image produced by a plane mirror is always the same size as the object, the same distance behind the mirror as the object in front, laterally inverted.

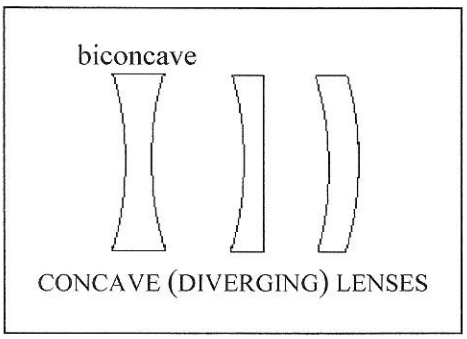
convex mirror A mirror which is a part of a sphere, with the silvering on the inside surface. A convex mirror is a *diverging* (↑) mirror.

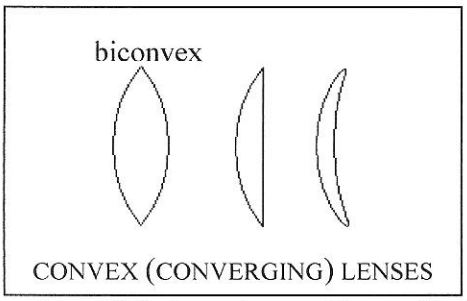
concave mirror A mirror which is a part of a sphere, with the silvering on the outside surface. A concave mirror is a *converging* (↑) mirror.



lens A piece of transparent material bounded by a spherical surface. Lenses are described by the nature of their boundary surfaces or by the effect they have on a beam of light.

concave lens This term is usually applied to a biconcave lens, *i.e.* a piece of transparent material bounded by two spherical surfaces. The surfaces curve inwards like the inside of a sphere. A concave lens is a *diverging* (↑) lens.



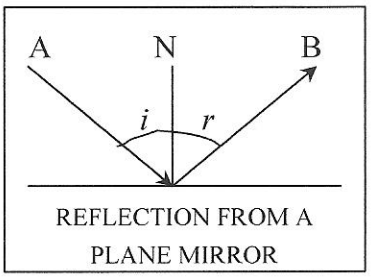


convex lens This term is usually applied to a biconvex lens, *i.e.* a piece of transparent material bounded by two spherical surfaces. The surfaces curve outwards like the outside of a sphere. A convex lens is a *converging* (↑) lens.

reflect **1.** To return a beam of radiation, causing it to return to the medium from which it started. **2.** (Of a *beam* (↑) of radiation) to return at an interface between two media. – ***reflecting, reflected*** *(adj.)*, ***reflection*** *(n.)*

reflecting Describes a surface which reflects light or other waves, *e.g.* the surface of mercury is a reflecting surface. – ***reflect*** *(v.)*, ***reflected*** *(adj.)*, ***reflection*** *(n.)*

reflection The process by which a beam of radiation, such as light, may be deviated and reversed in direction by an opaque surface. If the surface is smooth, reflection is *regular* (↓); if the surface is rough, reflection is *diffuse* (↓). Reflection can also take place at the interface between two media of different *refractive index* (↓). Not all the radiation is reflected; some may *be refracted* (↓). When the radiation passes from a dense to a less dense medium, total reflection may take place. Depending upon the nature of the beam of radiation, some *wavelengths* (→)[1] may be absorbed and others reflected. Thus when *white light* (→)[2] is *incident* (↓) on a red surface, the red wavelengths are reflected and others are absorbed. – ***reflect*** *(v.)*, ***reflecting, reflected*** *(adj.)*



laws of reflection The law that **1.** the *incident* ray (*A*), the *reflected* (↑) ray (*B*), and the normal (*N*) at the point of incidence (↓), all lie in the same plane, **2.** the angle of incidence (*i*) is equal to the angle of reflection (*r*).

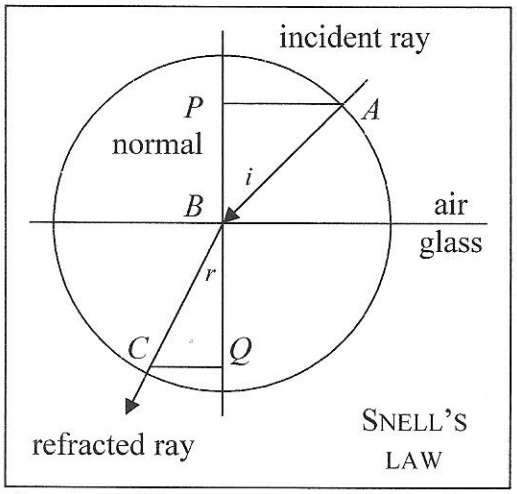
incidence The action of radiation or a moving body arriving at or falling on a surface. – ***incident*** *(adj.)*

regular Describes the type of *reflection* (↑) obtained from a homogeneous, continuous surface. A parallel beam is reflected as a parallel beam and there is no scattering of light. The reflection from a sheet of highly polished plane glass which has been silvered will be regular reflection.

diffuse Describes *reflection* (↑) which is irregular. The light is scattered in all directions because the surface is uneven and provides a very large number of tiny reflecting surfaces. A sheet of paper or a sheet of ground glass produces diffuse reflection. Even a piece of coloured material, such as wool, must be reflecting in order to be coloured.

[1] – see "THEORIES OF LIGHT" (Set B)

[2] – see "SPECTRA"



refraction The process which takes place when a ray of light, or other electromagnetic radiation, passes from a less dense to a denser medium, *e.g.* from air to glass. If the direction of the ray is normal to the surface, it passes through without change of direction. If the direction of the ray is at an angle to the normal then the ray will be deflected towards the normal. This process of deflection of a ray by a material medium is called refraction. The *waves* (→)[1] in the medium are deflected because the *velocity* (→)[2] of the waves in the medium is less than their velocity in air. – ***refract** (v.), **refracted** (adj.)*

Snell's laws The laws that, **1.** the *incident* (↑) ray, the *refracted* (↑) ray, and the normal are in one plane; the incident ray and refracted ray are on the opposite sides of the normal at the point of incidence; **2.** the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant: $\frac{PA \times CB}{AB \times QC} = \frac{\sin i}{\sin r} = \text{constant } n$

refractive index *Snell's law* (↑) states $\frac{\sin i}{\sin r} =$ constant for a given medium, where i and r are the angles of *incidence* (↑) and *refraction* (↑), respectively. This constant is called the refractive index (n). Unless otherwise stated it is a property of the medium with respect to air as unity. The symbol may be written as ${}_{a}n_{g}$, meaning the refractive index of air to glass. If the value of n is determined for a particular frequency, *e.g.* the sodium D line, then the refractive index is written n_D. It can be shown also that for a given frequency n = v_1/v_2, where v_1 is the velocity of light in air and v_2 is the velocity of light in the medium.

[1] – see "THEORIES OF LIGHT" (Set B)
[2] – see "KINEMATICS"

Task IV. Read the definitions of the terms from "Longman Dictionary of Scientific Usage" and then do the following exercises.

I. **Opposites** *Look at these lists of words. Each one in Group A has an opposite in Group B. Match them and then find the definition below to each of these words.*

Group A	*Group B*
1. diminish	6. converge
2. diverge	7. rough
3. opaque	8. concave
4. convex	9. magnify
5. smooth	10. transparent

Definitions:

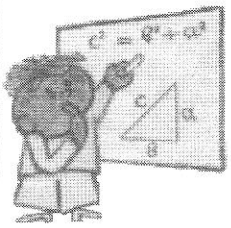
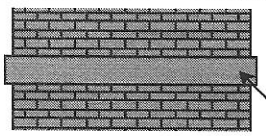
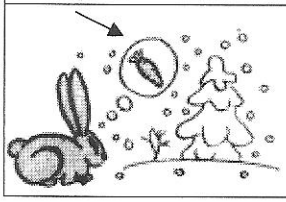
a) (of a beam of radiation) to become the narrower, the further it travels
b) having an uneven or irregular surface
c) that can be seen through
d) to make (something) seem larger than it is
e) curved outwards, like the outside edge of a circle
f) to (cause to) become or seem smaller
g) having an even surface with no projections
h) (of a beam of radiation) to grow the wider, the further it travels
i) not allowing light to pass through
j) curved inwards, like the inside surface of a hollow ball

II. Scientific and Everyday English

A) Many scientific and technical words are used in everyday English. Choose the most suitable word from the middle column to complete the sentences of the first and last columns.

Everyday English	*Words*	*Scientific English*
1. The actor drank … wine on the stage. 2. The roads … just before the station. 3. She is a good student and … new ideas quickly. 4. Does the composition … your real opinion? 5. A fish in water is in its natural … . 6. You must drive at a … speed if you want to save petrol.	**regular** **real** **absorb** **converge** **reflect** **medium**	1. The process of deflection of a ray by a material … is called refraction. 2. White colours … light and dark colours … it. 3. A convex lens … a beam of light. 4. The reflection from a highly polished surface is a … reflection 5. An image of a body may be … or virtual.

B) The words in the middle column below all have more than one meaning. Match each of them with a picture and definition of everyday English and with a definition of scientific English.

Everyday English	*Terms*	*Scientific English*
 1) a person, especially child, who is being taught	**beam**	b) a solid object with a round base and a point at the top
 2) an instrument, containing black or coloured graphite, used for drawing or writing	**pupil**	c) a collection of light rays
 3) a large long heavy piece of timber or metal, carrying the weight of part of a building	**pencil**	d) a copy produced by a mirror or lens of an object
 4) a dry scaly fruit of pine or fir	**image**	e) the small black round aperture in the middle of the coloured part of the eye, through which light passes
 5) a picture, especially in the mind (mental picture)	**cone**	f) a slender cylinder or cone of rays which passes through an optical system

Task V. Let's play the game 'Research Conference'. The instructions are given on pages 170 – 172. Discuss the following topics:

- **Branches of Optics:**
  - ✓ **Photometry.**
  - ✓ **Geometrical Optics**
- **Reflection of Light**
- **Refraction of Light**

Stage 5 – In Addition

Experiments

Experiment 1

It seems strange that a ray of light refracts while passing through one medium to another. Why does not light keep its original direction? Why does it choose a deflected way? The following experiment illustrates the refraction of light.

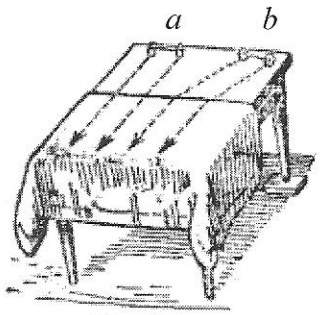


Fig. 1

You need **a table**, **a table-cloth**, and **an empty spool**.

Cover a half of the table with a tablecloth. Incline the table slightly and make a spool roll down it. If the direction of the spool and the edge of the table-cloth are normal to each other, the deflection of way does not occur (*Fig. 1, a*). In this case we have an illustration of the law: if the direction of the ray is normal to the interface, it passes through without change of direction.

If the direction of the spool is at an angle to the edge of the table-cloth, the way of the spool is deflected (*Fig. 1, b*). It is easy to notice that while rolling down from the uncovered part of the table (where the velocity of a moving spool is higher) to the covered one (where the velocity is less), the direction of the spool is deflected towards the normal. And vice versa, if the spool rolls down from a covered part to the uncovered one, you can notice that the direction of the spool is deflected from the normal (*Fig 2*).

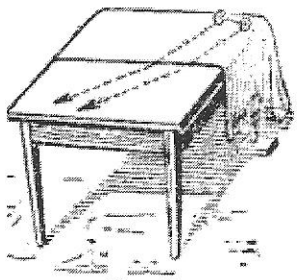


Fig. 2

This illustrates the essence of the examined phenomenon, *viz.* the refraction is caused by the difference of light velocities in both media. The greater the difference between the velocities, the more considerable is the refraction of light. The so-called refractive index is none other than the ratio of these velocities. For instance, if the refractive index of air to water is 4/3, it means that a ray of light passes through air approximately 1.3 times as fast as it passes through water.

Experiment 2

You need **a bowl** (or **a cup**), **a coin** and **some water**.

Ask your friend to sit down so that he cannot see the bottom of the cup standing in front of him. There is a coin at the bottom. So your friend cannot see the coin (*Fig. 3*). Then fill the cup with water. What does your friend observe? The bottom seems to rise and your friend can see the coin (*Fig. 4*)! The definition given below accounts for this phenomenon.

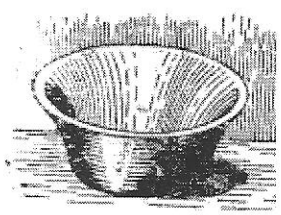


Fig. 3

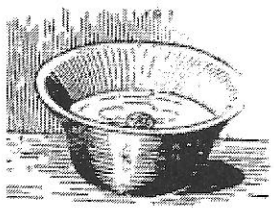


Fig. 2

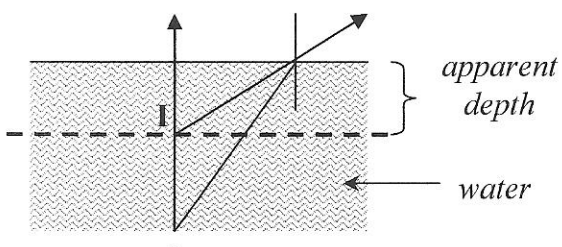


Fig. 5

apparent depth An object in water, when viewed from above, appears to be at a shorter distance below the water than it really is. The light from the objects does not come directly to the eye but is refracted at the air/water boundary. It can be shown that the real depth is n times the apparent depth, where n is the refractive index of water.

Experiment 3

Teacher of physics: What do you see looking in the mirror?
Student: I can see my own copy.
Teacher: Really? Is it your own copy?
Student: Of course! It is like me to the smallest detail.

Do you agree with the student? Let us examine the situation.

Your hair is parted at the left side, but your mirror image's hair is parted at the right one. There is a handkerchief in your right-hand pocket, but your mirror image has put it into their left-hand one. If you are a right-handed person, they write, eat, and draw with their left hand. When you want to greet your mirror image and shake their hand, they reach out their left hand for greetings. You hold a book in your right hand, but your mirror image holds it in their left one. By the way, pay attention to their book. It is very difficult to read even the only line from it.

Just think! This is a man pretending to be absolute same to you! And looking at them you hope to have an idea of your appearance! The difference between you and your mirror double will seem to be more appreciable if you conduct the following experiment.

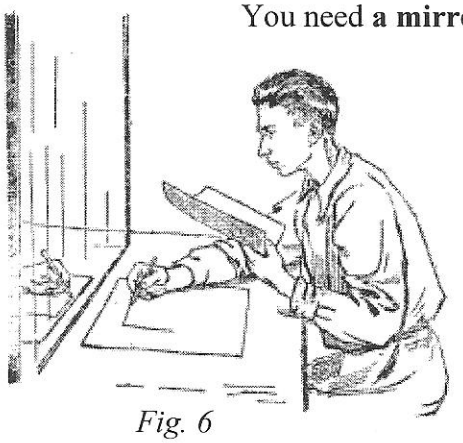


Fig. 6

You need **a mirror**, **a sheet of paper** and **a pen** (or **a pencil**).

Sit down in front of the mirror and try to draw any figure, for example a star, following your hand reflected from the mirror (*Fig. 6*). You will make sure that such an easy task appears to be almost impossible! You want to draw a line to the right, but your hand moves to the left. Let us complicate the task. Try to write something in this way. Then ask your friend to read your notes. Is it possible for him to do that? I do not think so. Set the sheet of paper against the mirror at a right angle and your friend will read your notes without any difficulty. An excellent way to codify letters!

Think and Guess

1. Funny Box

Fig. 7 represents a cube in the mirror corner.
What is the surface of the original cube (Fig. 8)?

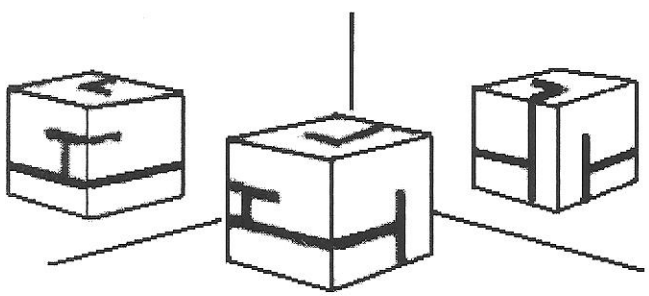


Fig. 7

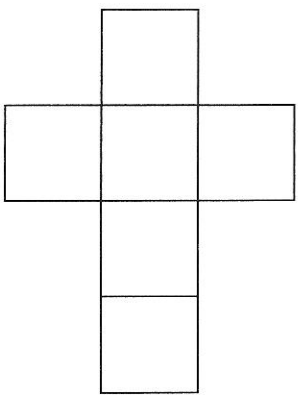


Fig. 8

2. Light Boomerang

In Fig. 9 you can see a box containing mirror internal sides. There are two small slits in one of its sides. A ray of light is allowed to pass through slit A and almost immediately a reflected ray of light passes through slit B (Fig. 10). Can you show the path of the ray inside the box?

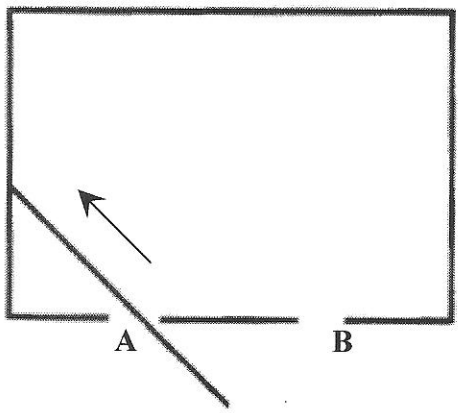


Fig. 9

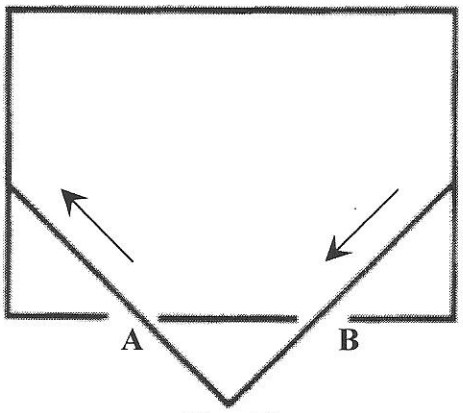
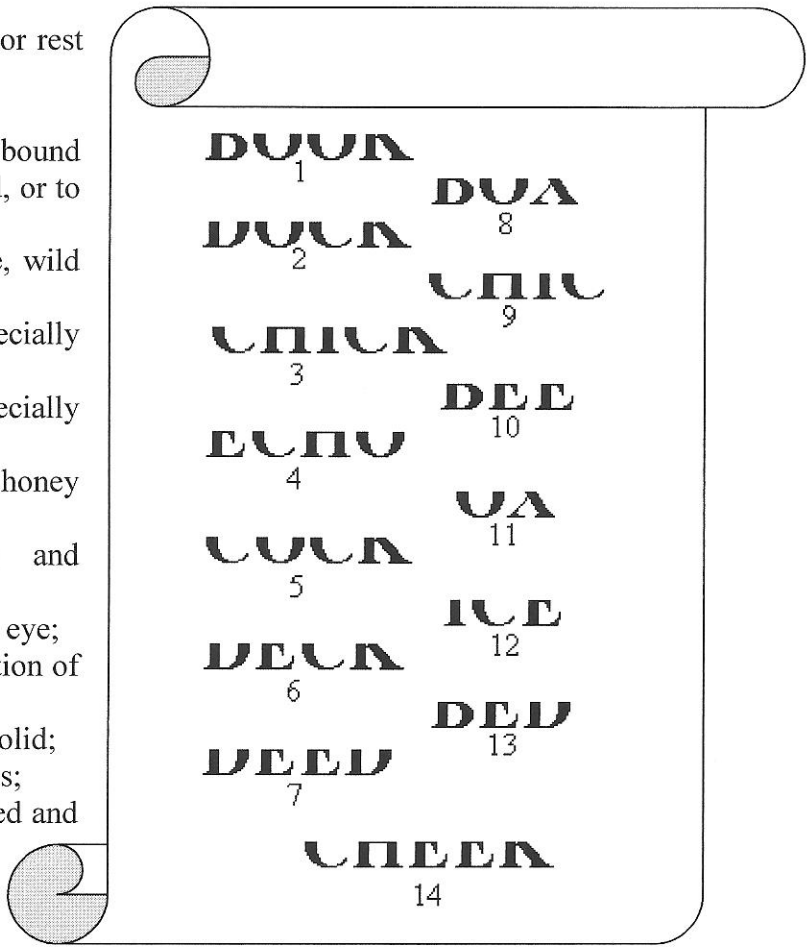


Fig. 10

3. Codified Words

Read these codified words with the help of a mirror. Then match each of them with its definition.

a) a piece of furniture to sleep or rest on;
b) a container with a flat base;
c) a set of sheets of papers bound together as a thing to be read, or to be written in;
d) a large animal of cattle type, wild or domestic;
e) a fully-grown male bird, especially a chicken;
f) the young of any bird, especially of chicken;
g) a stinging insect that makes honey and lives in groups;
h) (showing) a good style and elegance;
i) the part of the face below the eye;
j) repetition of sound by reflection of sound waves;
k) water which has frozen to a solid;
l) floor or storey of a ship or bus;
m) a place where ships are loaded and unloaded, or repaired;
n) thing done, act.



Intriguing Physics

Optical Illusions

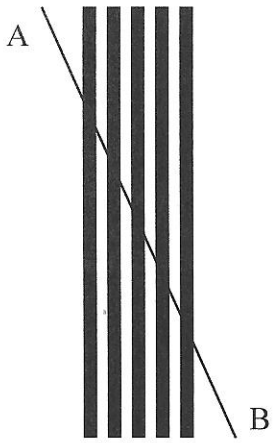


Fig. 1

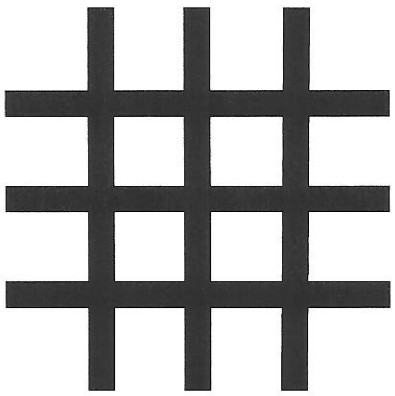


Fig. 2

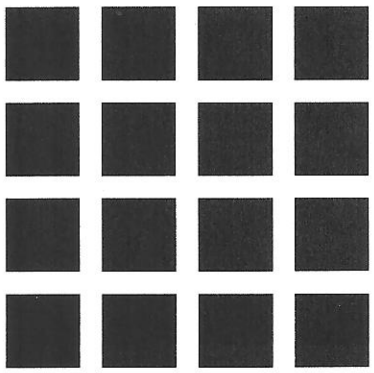


Fig. 3

Figure 1. The line AB seems to be broken although it is quite straight.

Figure 2. Grey spots appear and disappear on the crossing of black lines. In reality the lines are absolutely black.

Figure 3. Grey spots appear and disappear on the crossing of white lines, although they are absolutely white.

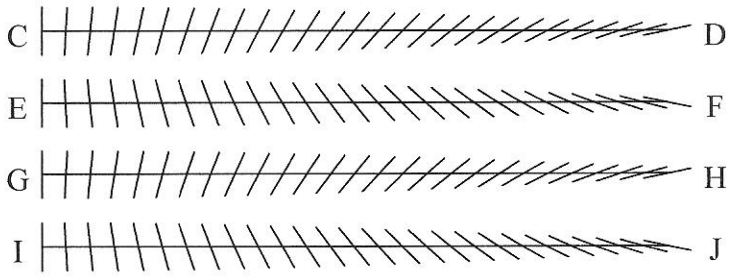


Fig. 4

Figure 4. Lines CD, EF, GH, and IJ seem to be nonparallel although they are parallel.

A Power of Imagination

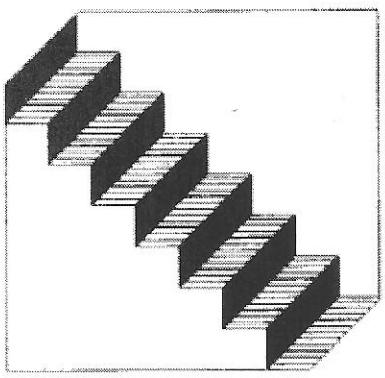


Fig. 5

Figure 5. What can you see here?

Some people see a staircase, and others – a niche[1] in the wall. But there are people who believe a pleated[2] piece of paper to be drawn here. Strange as it may seem, all the answers are correct! You can see all these objects looking at the picture in different ways. If you look at the left part of the picture you will see a staircase. If you direct your eyes from right to left you will see a niche. And at last you can see a pleated piece of paper, if you turn your eyes diagonally from the lower right edge to the upper left one.

Figure 6. What can see you in the picture? Are there two cubes at the bottom or at the top of the figure?

You can see two cubes both at the bottom and at the top of the figure if you look at the picture in different ways.

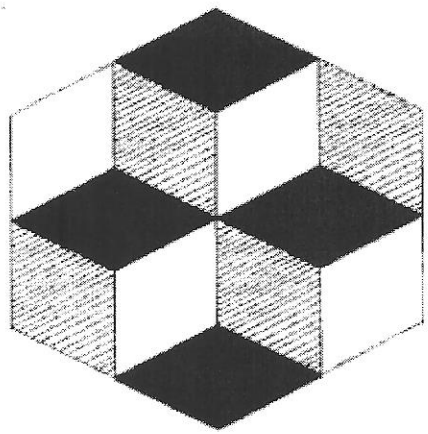


Fig. 6

[1] **niche** [nɪtʃ] a hollow place in a wall

[2] **pleat** [pli:t] 1) a narrow fold of cloth or paper; 2) to make pleats in

(from "Active Dictionary of English")

Which is Bigger?

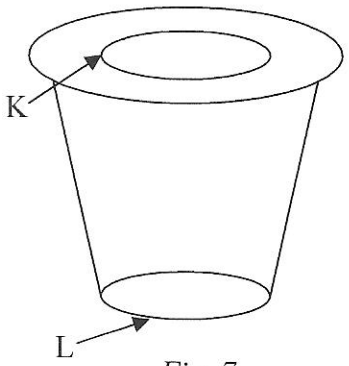


Fig. 7

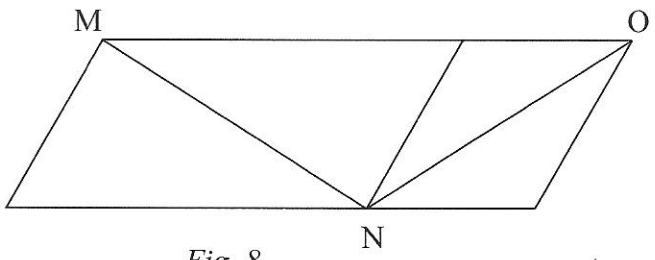


Fig. 8

Figure 7. Which of the ellipses is bigger, K or L?
Figure 8. Which line is longer, MN or NO?
Figure 9. Which is longer, the length or the breadth of the figure?
Figure 10. Which of the figures is wider, P or Q? Which is longer, the length or the breadth of figure P? Which is shorter, the length or the breadth of figure Q?

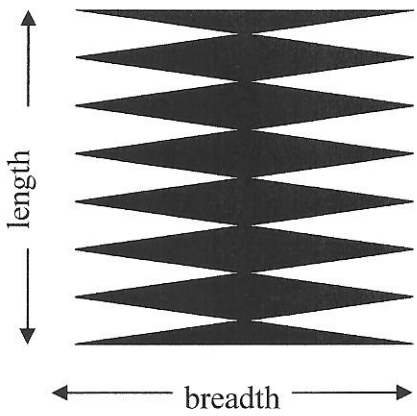


Fig. 9

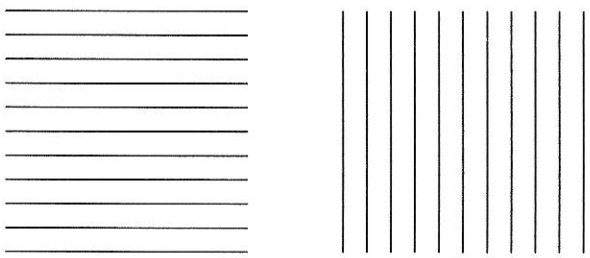


Fig. 10

Answers:

Figure 7. The two ellipses are equal, although ellipse L seems to be bigger than ellipse K.
Figure 8. Line MN seems to be longer than line NO, but they are quite equal.
Figure 9. It is difficult to believe that the length of the figure is equal to its breadth.
Figure 10. Figure P seems to be narrower than figure Q. As far as the length of figure P is concerned it seems to be longer than its breadth. And vice versa, it seems that the length of figure Q is shorter than its breadth, although both figures (P and Q) represent absolutely equal squares.

Thus, all the comparable figures and quantities are equal! You can be convinced in the truth of this statement by means of a ruler or a pair of compasses[1].

[1] **compass** ['kʌmpəs] an instrument for showing direction, usually consisting of a freely-moving needle which always points to the north
a pair of compasses a V-shaped instrument used for drawing circles, measuring distances on maps, *etc.*
(from "Active Dictionary of English")