# 3B SCIENTIFIC® PHYSICS

...going one step further

# Basic Experiments in Optics on the Optical Bench U17145

## Instruction sheet

05/11/ALF/MEC

## 1. Overview of the Experiments

| | |
|---|---|
| Experiment 1: | Demonstration of the various ray beams |
| Experiment 2: | Reflection of a ray of light from a plane mirror |
| Experiment 3: | Reflection of a light beam from a plane mirror |
| Experiment 4: | Reflection of a light beam from a concave or convex mirror |
| Experiment 5: | Snell's law of refraction |
| Experiment 6: | Refraction of light through a planeparallel plate |
| Experiment 7: | Refraction of light through a prism |
| Experiment 8: | Inverting prisms |
| Experiment 9: | Concave and convex lenses |

## 2. Scope of delivery

1 Optical bench U, 120 cm (U17150)
3 Optical rider U, 75 mm (U17160)
1 Optical rider U, 30 mm (U17161)
1 Experiment lamp, halogen (U17140)
1 Spare lamp, halogen 12 V, 50 W (U13735)
1 Object holder on a stem (U8474000)
1 Convex lens, $f$ = + 150 mm; 50 mm Ø (U17103)
1 Set of slits and apertures (U17040)
1 Optical disc with accessories (U17128)
1 Storage strip (U17120)

## 3. Safety instructions

- Warning! Lamps become extremely hot when operated for prolonged periods of time.
- Do not clean any of the optical components with aggressive fluids or solvents. This could cause damage!

## 4. Experiment examples

**Experiment 1: Demonstration of various ray beams**

### 1.1 Equipment

1 Optical bench
1 Experimental lamp
1 Object holder, shaft-mounted
1 Fivefold slit from U17040
1 Convex lens $f$ = +150 mm
3 Optical riders 75 mm
1 Optical rider 30 mm

**Additionally required:**

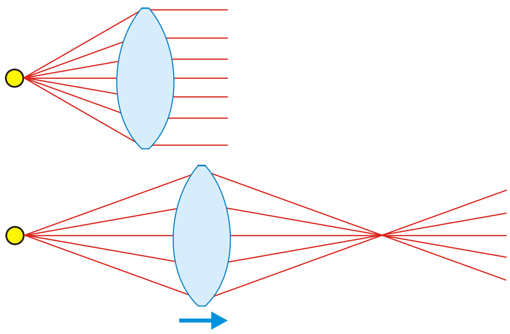
1 Transformer U13900
1 Projection screen U17130

### 1.2 Set up

- Place the experimental lamp horizontally on the rail at the 10 cm position.
- Place the object holder with five-fold slit horizontally on the rail at the 20 cm position.
- Place the convex lens at the 25 cm position.
- Mount the projection screen on the small rider.

### 1.3 Procedure

- When the convex lens is not used, the ray beam is divergent.
- When the convex lens is placed at the 25 cm position we obtain a parallel beam of rays.
- When the convex lens is moved away from the light source a converging beam of rays is produced.



**Experiment 2: Reflection of a ray of light from a plane mirror**

**2.1 Equipment**

1 Optical bench
1 Experimental lamp
1 Object holder, shaft mounted
1 Diaphragm with single slit from U17040
1 Convex lens $f$ = +150 mm
1 Optical disc
1 Plane mirror from U17128
3 Optical riders 75 mm
1 Optical rider 30 mm

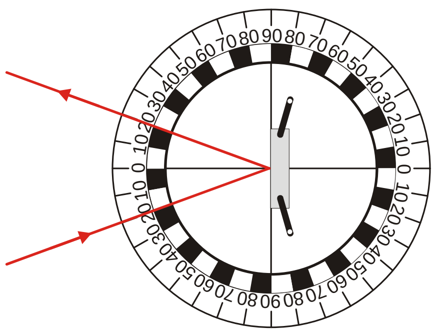
**Additionally required:**
1 Transformer U13900

**2.2 Set up**

- Place the experimental lamp horizontally on the rail at the 10 cm position.
- Place the object holder with single-slit diaphragm horizontally on the rail at the 20 cm position.
- Place the concave lens at the 25 cm position.
- Mount the optical disc with plane mirror on a small optical rider at the 40 cm position.

**2.3 Procedure**

- Fasten the plane mirror mounted on the optical disc to the 90° to -90° line.
- Set the height of the disc so that the incident light ray is reflected from the 0° line.
- By rotating the disc we can verify the law of reflection, which states that the angle of incidence is equal to the angle of reflection.



**Experiment 3: Reflection of a light beam from a plane mirror**

**3.1 Equipment**

1 Optical bench
1 Experimental lamp
1 Object holder, shaft mounted
1 Fivefold slit from U17040
1 Convex lens $f$ = +150 mm
1 Optical disc
1 Plane mirror from U17128
3 Optical riders 75 mm
1 Optical rider 30 mm

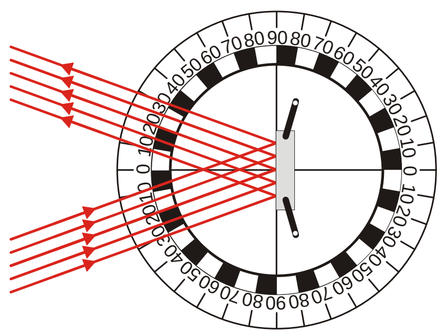
**Additionally required:**
1 Transformer U13900

**3.2 Set up**

- Place the experimental lamp horizontally on the rail at the 10 cm position..
- Place the object holder with the five-fold slit at the 20 cm position.
- Place the convex lens at the 25 cm position.
- Mount the optical disc with plane mirror on a small optical rider at the 40 cm position.

**3.3 Procedure**

- Attach the plane mirror on the optical disc at the 90°-90° line.
- Adjust the height of the disc so that the middle ray of light propagates along the 0° line and all rays are reflected into each other.
- By rotating the disc it is demonstrated that a parallel incident beam of light is also parallel after being reflected.
- By moving the lens away from the light source it can be demonstrated that a converging light beam is also reflected as a converging light beam.
- Without the use of the convex lens it can be demonstrated that a divergent light beam also diverges upon reflection.



**Experiment 4: Reflection of a light beam from a concave or convex mirror**

**4.1 Equipment**

1 Optical bench
1 Experimental lamp
1 Object holder, shaft mounted
1 Fivefold slit from U17040
1 Convex lens *f* = +150 mm
1 Optical disc
1 Plane mirror from U17128
3 Optical riders 75 mm
1 Optical rider 30 mm

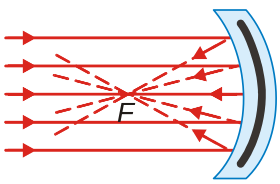
**Additionally required:**
1 Transformer U13900

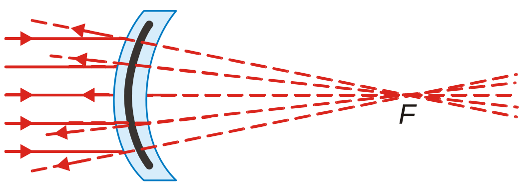
**4.2 Set up**

- Place the experimental lamp horizontally on the rail at the 10 cm position.
- Place the object holder with five-fold slit horizontally on the rail at the 20 cm position.
- Place the convex lens at the 25 cm position.
- Place the optical disc with convex mirror on the small rider at the 40 cm position.

**4.3 Procedure**

- Fasten the concave mirror on the optical disc on the 90°-90° line.
- Adjust the height of the disc so that the middle ray of light travels along the 0° line and is reflected into itself.
- Use the lens to generate a parallel beam.
- The incidenting rays are reflected so that they all pass through and converge at a single point *F*. This point is the focal point of the mirror.
- Repeat the experiment with converging and diverging light beams.
- Result: a concave mirror causes the rays to converge.
- Rotate the optical disc by 180° so that the incident rays are reflected by the convex mirror. Carry out the same procedural steps as stated above.
- A convex mirror causes the rays to diverge.




**Experiment 5: Snell's law of refraction**

**5.1 Equipment**

1 Optical bench
1 Experimental lamp
1 Object holder, shaft mounted
1 Diaphragm with single slit from U17040
1 Convex lens *f* = +150 mm
1 Optical disc
1 Semi-circular body from U17128
3 Optical riders 75 mm
1 Optical rider 30 mm

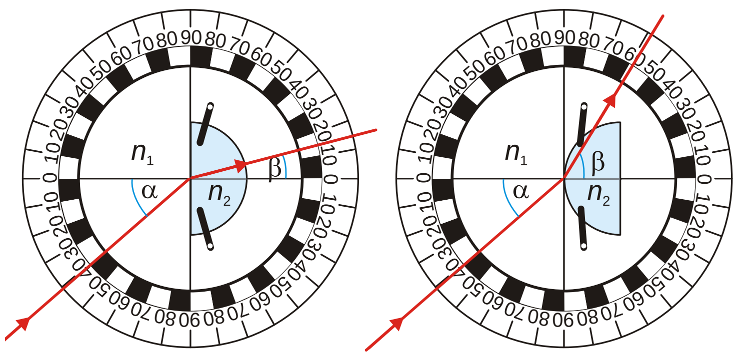
**Additionally required:**
1 Transformer U13900

**5.2 Set up**

- Place the experimental lamp horizontally on the rail at the 10 cm position.
- Place the object holder with single slot diaphragm horizontally on the rail at the 20 cm position.
- Place the concave lens at the 25 cm position.
- Mount the optical disc with semi-circular body on the small rider at the 40 cm position.

**5.3 Procedure**

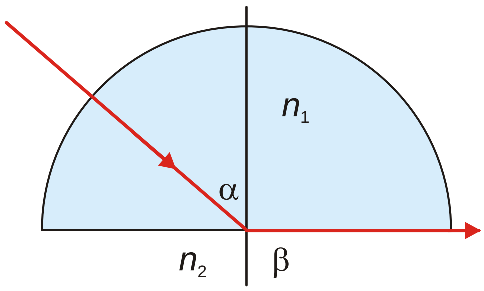
- Fasten the semi-circular body on the optical disc on the 90°-90° line so that the plane side is facing the light source.
- Adjust the height of the disc so that the incidenting light ray propagates along the 0° line and is incident at the precise center of the semicircular body. The ray of light then propagates uninterrupted along the 0° line.
- When the disc is rotated, the light ray is refracted toward the normal at the point of incidence.
- The disc is now rotated by 180° so that the convex disc is facing the light source. The light ray is now refracted away from the normal at the point of incidence.



- When the light ray passes from one medium with the refractive index $n_1$ to another medium with the refractive index $n_2$ its directional change is determined by Snell's law of refraction:

$$\frac{\sin\alpha}{\sin\beta} = \text{constant or } \frac{\sin\alpha}{\sin\beta} = \frac{n_1}{n_2}$$

- $\alpha$ is the angle of incidence in medium $n_1$ and $\beta$ is the angle of refraction in medium $n_2$.
- The bigger the angle of incidence is, the larger the angle of refraction becomes. If $n_1 < n_2$, there is a critical angle $\alpha$. At this angle the refracted ray of light is refracted along the interface between two media. If the angle of incidence is greater than the critical angle, then there is no longer any refraction and all light is reflected. This case is referred to as total internal reflection.




## Experiment 6: Refraction in a plane-parallel plate

### 6.1 Equipment

1 Optical bench
1 Experimental lamp
1 Object holder, shaft mounted
1 Diaphragm with single slit from U17040
1 Convex lens $f$ = +150 mm
1 Optical disc
1 Trapezoidal body from U17128
3 Optical riders 75 mm
1 Optical rider 30 mm

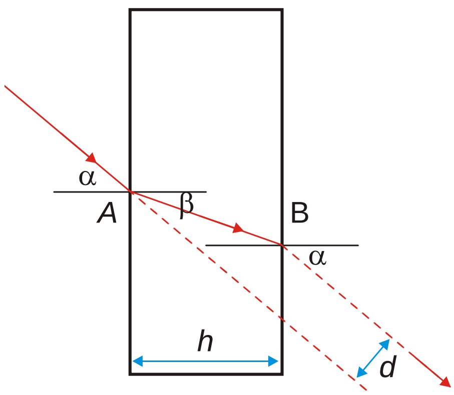
**Additionally required:**
1 Transformer U13900

### 6.2 Set up

- Place the experimental lamp horizontally on the rail at the 5 cm position.
- Set up the object holder including diaphragm with single slit at the 20 cm position.
- Place the concave lens at the 25 cm position.
- Set up the optical disc with trapezoidal body on the small optical rider at the 40 cm position.

### 6.3 Procedure

- Fasten the trapezoidal body on the optical disc along the 90° to -90° line so that its long side faces the light source. The middle section of the trapezoidal body acts like a plane-parallel plate.
- Adjust the height of the disc so that the incidenting light beam propagates on the 0° line and is not refracted by the trapezoidal body.
- Rotate the disc so that the beam is now refracted.
- The direction of the outgoing light ray is not altered.
- The outgoing light ray is nevertheless diverted from its original path by a distance $d$. For a plate of $h$ density, this gives the following for $d$: $d = h \cdot \frac{\sin(\alpha - \beta)}{\cos\beta}$




## Experiment 7: Refraction at a prism

### 7.1 Equipment

1 Optical bench
1 Experimental lamp
1 Object holder, shaft mounted
1 Diaphragm with single slit from U17040
1 Convex lens $f$ = +150 mm
1 Optical disc
1 Trapezoidal body from U17128
1 Right-angled prism from U17128
3 Optical riders 75 mm
1 Optical rider 30 mm

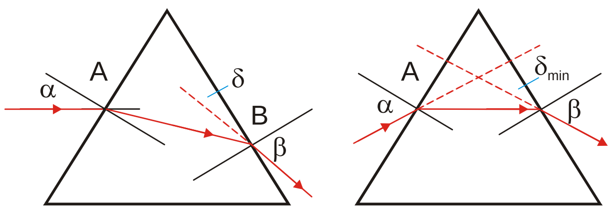
**Additionally required:**
1 Transformer U13900

### 7.2 Set up

- Place the experimental lamp at the 5 cm position.
- Set up the object holder with diaphragm including single slit at the 20 cm position.
- Place the concave lens at the 25 cm position.
- Set the optical disc with trapezoidal body on the small optical rider at the 40 cm position.

### 7.3 Procedure

- Fasten the trapezoidal body onto the optical disc along the 90° to -90° line so that the pyramid points upwards.
- Adjust the height of the disc so that the incident light ray travels on the 0° line.
- After the disc is rotated, the light ray incidents on the upper section of the trapezoidal body, which now functions, like a prism.
- In an acrylic prism the light ray incident at point A is refracted from the axis of incidence. At the emerging point B the ray is refracted away from the axis of incidence. The sum total of all refraction angles is called the deflection angle $\delta$. This is the angle between the incident and emerging light rays.
- It can be demonstrated that the incident angle $\alpha$ at the minimum deflection angle $\delta_{min}$ is equal to the emerging angle $\beta$. The refracted ray then propagates inside the prism parallel to the side, which is not passed through.




## Experiment 8: Inverting prisms

### 8.1 Equipment

1 Optical bench
1 Experimental lamp
1 Object holder, shaft mounted
1 Diaphragm with single and fivefold slit from
1 Convex lens $f$ = +150 mm
1 Optical disc
1 Right-angled prism from U17128
3 Optical riders 75 mm
1 Optical rider 30 mm

**Additionally required:**

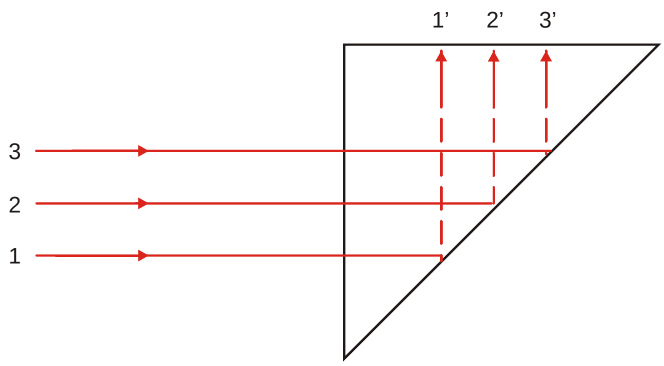
1 Transformer U13900

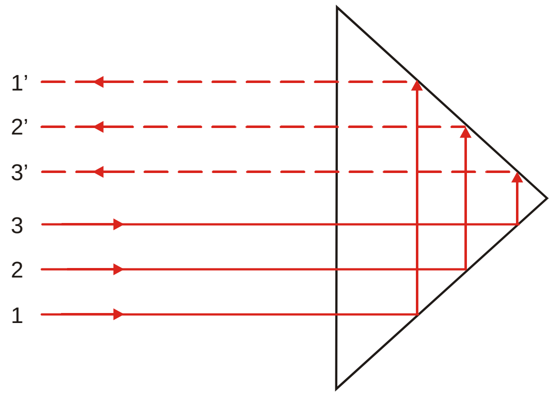
### 8.2 Set up

- Place the experimental lamp horizontally on the rail at the 5 cm position.
- Place the object holder including a diaphragm with single or five-fold slot horizontally on rail at the 20 cm position.
- Set up the concave lens at the 25 cm position.
- Set the optical disc with right-angled prism on the small optical rider at the 40 cm position.

### 8.3 Procedure

- Fasten the right-angled prism on the optical disc along the 90°-90° line so that the right angle is lined up with the 0° line and faces the light source.
- Adjust the height of the disc so that the incident light beam propagates on the 0° line.
- By rotating the disc all of the previously described phenomena can be observed.
- At a certain angle (limiting angle) the ray is subject to total internal reflection.
- Using the diaphragm with fivefold slit, it can be demonstrated that the rays can be reflected back in the direction from which they came.



## Experiment 9: Concave and convex lenses

### 9.1 Equipment

1 Optical bench
1 Experimental lamp
1 Object holder shaft-mounted
1 Diaphragm with fivefold slit from U17040
1 Concave lens $f = +150$ mm
1 Optical disc
Lenses from U17128
3 Optical riders 75 mm
1 Optical riders 30 mm

**Additionally required:**
1 Transformer U13900

### 9.2 Set up

- Place the experimental lamp horizontally on the rail at the 10 cm position.
- Set the object holder up with fivefold slit horizontally on the rail at the 22 cm position.
- Place the concave lens at the 27 cm position.
- Set up the optical disc with lens on the small optical rider.

### 9.3 Procedure

- Place the convex lens in a central position on the optical disc.
- Adjust the height of the disc so that the center of the incident light beam propagates on the 0° line.
- A convex lens is a converging lens. After passing through the medium the light rays all converge at the focal point *F*.
- Repeat the experiment using the concave lens.
- The light rays diverge after passing through the lens. No image of an object emerges. Tracing the divergent rays backwards one arrives at a virtual focal *F*' where these lines meet.