

COURSE

Photography Fundamentals

10 Chapters

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PHOTOGRAPHY FUNDAMENTALS

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Photography Fundamentals

Course 1 · Chapter 1 · Exposure Basics: Aperture, Shutter Speed and ISO

What Exposure Is

Every photograph is a measured amount of light. Wikipedia's Exposure article defines exposure as the amount of light per unit area reaching a frame of film or the surface of an electronic image sensor, and says it depends on the exposure time, the lens f-number and the luminance of the scene. This chapter is about those three controls and how to trade one against another without changing the brightness of the picture.

CONTROL	WHAT IT CHANGES	SIDE EFFECT
Aperture	Size of the lens opening	Opening it up increases exposure but decreases depth of field
Shutter speed	How long the sensor is exposed	A slower shutter increases exposure but also increases motion blur
ISO	Sensitivity setting (film speed on film)	A higher ISO needs less exposure for a readable image; noise is covered later in the course (check)

> **THE "EXPOSURE TRIANGLE"**
>
> Many tutorials call these three controls the exposure triangle. The Wikipedia article does not use that phrase, so treat it as common teaching vocabulary rather than a formal term (check).

Stops: Doubling and Halving

Photographers measure changes in light in **stops**. One stop more is twice as much light; one stop less is half as much. The article describes a "+1" exposure compensation setting as one stop more, meaning twice as much exposure.

Aperture and the f-number

The f-number N is the focal length divided by the diameter of the entrance pupil: a 100 mm lens with a 50 mm pupil is f/2. A **larger** f-number means a **smaller** opening and less light. The usual full-stop series is:

```
# Full-stop f-numbers (each step halves the light)
f/1   f/1.4   f/2   f/2.8   f/4   f/5.6   f/8   f/11   f/16   f/22
```

Each step multiplies the number by roughly the square root of 2 (about 1.414). That shrinks the opening diameter by about 0.7071 and, because area goes with the square of diameter, halves the area and so the light. The exact values are powers of the square root of 2; the printed numbers are rounded (the exact value near 5.66 is written 5.6, and near 22.6 is written 22).

Shutter Speed

The standard series from the Shutter speed article is 1/1000, 1/500, 1/250, 1/125, 1/60, 1/30, 1/15, 1/8, 1/4, 1/2 and 1 second. Each step is a 2:1 ratio, so it changes the light by one stop. Slower speeds record more movement as blur. A hand-holding rule of thumb in the article: the slowest speed you can usually manage without noticeable shake is the one numerically closest to the lens focal length, so about 1/60 s for a 50 mm lens and no slower than 1/200 s for a 200 mm lens. Demanding enlargements may need faster speeds.

> **RULE OF THUMB, NOT A GUARANTEE**
>
> The focal-length rule is a guide for steady hands. Image stabilisation, your own steadiness and the final print size all change what works for you; I have not tested stabilised lenses here (check).

Trading One for Another: Exposure Value

Exposure Value (EV) puts aperture and shutter time on one scale: EV = log2(N squared / t), where N is the f-number and t is the time in seconds. EV 0 is 1 second at f/1.0. Different pairs with the same EV give the same exposure at a given ISO. The tables in the Exposure value article assume ISO 100; for another ISO S, EV(S) = EV(100) + log2(S/100), so ISO 400 adds 2.

The script below computes EV, and I ran it to get the output shown.

```
from math import log2

def ev(n, t):
    return log2(n * n / t)

for n, t in [(1.0, 1), (16, 1/100), (8, 1/250), (5.6, 1/500), (2.8, 1/60)]:
    print(f"f/{n} at {t:.4f}s -> EV {ev(n, t):.2f}")
```

```
# Output
f/1.0 at 1.0000s -> EV 0.00
f/16 at 0.0100s -> EV 14.64
f/8 at 0.0040s -> EV 13.97
f/5.6 at 0.0020s -> EV 13.94
f/2.8 at 0.0167s -> EV 8.88
```

WHY THE NUMBERS ARE NOT WHOLE

The second, third and fourth lines come out near EV 14 to 14.6 rather than exactly equal because the printed f-numbers and speeds are rounded (5.6 is really about 5.66, and 1/250 and 1/500 are not exact halvings of 1/100). Camera settings are close to, not exactly, the same exposure. The first line gives EV 0, matching the stated reference.

Typical EV values at ISO 100

SCENE	EV
Light sand or snow in full sunlight	16
Typical scene, full or slightly hazy sunlight	15
Typical scene, cloudy bright (no shadows)	13
Typical scene, heavy overcast	12
Bright street scenes	8
Home interiors	5 to 7

The Sunny 16 Rule

The Exposure article gives a quick no-meter starting point: on a sunny day at f/16, use a shutter speed of one over the film speed (or the closest equivalent), so ISO 100 film gets 1/100 s. Checking against the script: f/16 at 1/100 s is EV 14.64, which sits between the table's 15 for sunlight and 13 for cloudy bright, so the rule is a sensible starting point rather than an exact match (my own observation; check).

Not Yet Verified, and Sources

- **Sources.** Wikipedia articles Exposure (photography), Exposure value, F-number and Shutter speed. The F-number page text was read to about 100,000 of 106,003 characters; the last 6,000 were not read.
- **Not in those pages.** The phrase "exposure triangle"; the effect of ISO on noise; image stabilisation (all marked check).
- **Not tested.** I did not test the focal-length rule with real lenses.

Exercises

EXERCISE 1

Starting from f/2.8, list the next four full stops to a smaller opening. For each step say what happens to the light, and how many stops separate f/2.8 from f/11.

→ Solution

EXERCISE 2

A correct exposure is f/8 at 1/125 s. You want a wider opening of f/4 to blur the background. Which shutter speed from the standard series keeps the exposure the same? Then use the EV script to confirm both pairs give nearly the same value.

→ Solution

EXERCISE 3

The article gives night sports as EV 9 at ISO 100. What is its EV at ISO 400 using EV(S) = EV(100) + log2(S/100)? And what is the longest shutter speed (nearest in the standard series) you would pick for a

handheld 100 mm lens, using the focal-length rule of thumb?

→ Solution

QUICK REFERENCE

- **Exposure:** light per unit area reaching the sensor
- **One stop:** double or half the light
- **f-numbers:** 1, 1.4, 2, 2.8, 4, 5.6, 8, 11, 16, 22
- **Shutter:** 1/1000, 1/500, 1/250, 1/125, 1/60, 1/30, 1/15, 1/8, 1/4, 1/2, 1 s
- **EV:** log2(N squared / t); EV 0 = 1 s at f/1.0
- **Sunny 16:** f/16 and 1/ISO seconds

COMING NEXT

Photography Fundamentals 2 looks at the camera and lens in more detail.

Focal Length and Angle of View

Photography Fundamentals 1 covered how much light reaches the sensor. This chapter covers *how much of the scene* the lens takes in. The lens's focal length, together with the size of the sensor, sets the **angle of view**. A shorter focal length gives a wider angle and a longer one a narrower angle.

Wikipedia's Angle of view article gives the formula $\alpha = 2 \arctan(d / 2f)$, where d is the sensor dimension being measured (width, height or diagonal) and f is the focal length. The script below applies it to a 36 by 24 mm sensor (the "35 mm full frame" size, diagonal 43.3 mm) and I ran it to get the output shown.

```
from math import atan, degrees, hypot

def angle(d, f):
    return degrees(2 * atan(d / (2 * f)))

W, H = 36, 24
diag = hypot(W, H)
print(f"diagonal {diag:.1f} mm")
for f in (24, 35, 50, 85, 200):
    print(f"{f} mm: horizontal {angle(W, f):.1f}, diagonal {angle(diag, f):.1f}")
crop = diag / hypot(23.7, 15.6)
print(f"APS-C crop factor {crop:.2f}; 50 mm equals {50 * crop:.0f} mm")
```

```
# Output
diagonal 43.3 mm
24 mm: horizontal 73.7, diagonal 84.1
35 mm: horizontal 54.4, diagonal 63.4
50 mm: horizontal 39.6, diagonal 46.8
85 mm: horizontal 23.9, diagonal 28.6
200 mm: horizontal 10.3, diagonal 12.3
APS-C crop factor 1.52; 50 mm equals 76 mm
```

The 50 mm line matches the article's own worked example (39.6, 27.0 vertical and 46.8 degrees diagonal).

Lens Types by Focal Length

The Normal lens article says a lens whose focal length is close to the frame diagonal (about 43 mm on full frame) gives a "natural" view; 50 mm is the most common choice, and roughly 40 to 58 mm counts as normal. Shorter is wide-angle, longer is telephoto (a common kind of long-focus lens). The Angle of view article groups them by diagonal angle:

TYPE	FOCAL LENGTH (FULL FRAME)	DIAGONAL ANGLE
Wide-angle	24 to 35 mm	about 84 to 64 degrees
Standard	36 to 60 mm	about 62 to 40 degrees
Medium telephoto	85 to 250 mm	about 30 to 10 degrees
Super telephoto	over 300 mm	under 8 degrees

CHECK YOUR NUMBERS AGAINST THE TABLE

The script gives 84.1 degrees for 24 mm, 63.4 for 35 mm, 28.6 for 85 mm and 12.3 for 200 mm, all inside the table's ranges. The ranges are descriptive groupings from one article, not an official standard (check).

Sensor Size and the Crop Factor

A smaller sensor sees a narrower slice of what the lens projects, so the same lens gives a narrower angle. The Crop factor article defines the crop factor as the 35 mm frame diagonal (43.3 mm) divided by the sensor diagonal. Multiply the focal length by it to get the full-frame focal length with the same field of view. The lens's real focal length does not change.

FORMAT	SENSOR (MM)	CROP FACTOR
Full frame 35 mm	36 by 24	1.0
Canon APS-C	22.2 by 14.8	1.6

FORMAT	SENSOR (MM)	CROP FACTOR
General APS-C (Nikon DX, Sony, Fujifilm X and others)	23.7 by 15.6	1.5
4/3" Four Thirds	17.3 by 13.0	2

EQUIVALENT IS ABOUT THE VIEW, NOT THE LIGHT

The factor describes field of view only. The article's example is a 50 mm lens on a 1.6 times sensor framing like an 80 mm on full frame. It does not mean the lens "becomes" an 80 mm in any other respect. How sensor size affects depth of field and noise is outside this chapter (check).

Prime and Zoom

A prime lens has one fixed focal length; a zoom covers a range. These two terms are standard photography vocabulary, but I did not check a source for them in this session (check). A practical point from Chapter 1: lenses are also described by their widest aperture (for example f/1.8 or f/2.8), the lowest f-number they allow, which sets how much light they can gather.

Not Yet Verified, and Sources

- **Sources.** Wikipedia articles Angle of view (photography), Normal lens and Crop factor. Each answer was read through a page summary, not the full text, so details beyond what is quoted here were not seen.
- **Not in those pages.** The definitions of prime and zoom, the effect of sensor size on depth of field and noise, and whether the handheld rule should use actual or equivalent focal length (all check).
- **Conflict to note.** The Crop factor page lists Canon APS-C as 1.6 and other APS-C as 1.5; my script's 1.52 uses the 23.7 by 15.6 mm size. Both figures are right for their sensors.

Exercises

EXERCISE 1

Edit the script to find the horizontal angle of a 35 mm lens on full frame (36 mm wide) and on a 23.7 mm wide APS-C sensor. Which is wider, and what full-frame focal length does the APS-C view match,

using the crop factor?

→ Solution

EXERCISE 2

Using the script and the lens-type table, compute the diagonal angle for 24, 50, 85 and 300 mm on full frame and name the type each falls into.

→ Solution

EXERCISE 3

A 200 mm lens is fitted to a Four Thirds camera (crop factor 2). What full-frame focal length does it match for field of view? Then apply Chapter 1's handheld rule of thumb to the lens's actual focal length and name the shutter speed from the standard series. State one thing you are unsure of.

→ Solution

QUICK REFERENCE

- **Angle of view:** 2 arctan(d / 2f)
- **Normal lens:** about 43 mm on full frame; 50 mm common
- **Crop factor:** 43.3 mm divided by the sensor diagonal
- **Values:** APS-C 1.5 (Canon 1.6), Four Thirds 2
- **Check:** prime and zoom definitions, sensor size effects beyond view

COMING NEXT

Photography Fundamentals 3 takes up depth of field and focus, which bring Chapter 1's aperture together with this chapter's focal length.

Photography Fundamentals

Course 1 · Chapter 3 · Depth and Focus: Depth of Field and Autofocus

What Depth of Field Is

Only one distance is truly in focus, but a band around it looks acceptably sharp. Wikipedia's Depth of field article describes depth of field (DOF) as the distance between the nearest and the farthest objects that appear in acceptably sharp focus. Photography Fundamentals 1 noted that opening the aperture decreases depth of field; Photography Fundamentals 2 gave the focal length and sensor size. This chapter brings them together.

What Controls It

The article gives an approximate formula, DOF = 2 u squared N c / f squared, for subject distance u, f-number N, circle of confusion c and focal length f. The circle of confusion is the largest blur spot that still looks like a point. Reading the formula:

CHANGE	EFFECT ON DOF (PER THE ARTICLE)
Wider aperture (lower N)	Reduces DOF; DOF grows in proportion to the f-number for a fixed framing
Subject distance	Changes with the square of the distance
Focal length	Changes inversely with the square of the focal length
Circle of confusion	Changes linearly with c
Sensor size	With focal length and aperture held constant, a smaller sensor reduces DOF by the crop factor

APPROXIMATION ONLY

The article calls the formula approximate. It is a reasonable guide at ordinary distances, but I have not checked how far it drifts at very close range (check). The article's circle-of-confusion values (0.25 mm viewed from 25 cm; 0.025 mm for 16 mm film and modern 35 mm motion pictures) are not for stills

cameras. The 0.03 mm I use below is a common convention for full-frame stills that this source did not confirm (check).

Trying the Formula

The script below applies the approximation. I ran it and the output is shown.

```
def dof(u, f, n, c):
    """Approximate depth of field in mm: 2*u^2*N*c / f^2"""
    return 2 * u * u * n * c / (f * f)

c = 0.03
for u, f, n in [(2000, 50, 2.8), (2000, 50, 5.6), (2000, 50, 11), (4000, 50, 2.8), (2000
    print(f"u={u/1000:.0f} m f={f} mm f/{n}: DOF about {dof(u, f, n, c)/1000:.2f} m")
```

```
# Output
u=2 m f=50 mm f/2.8: DOF about 0.27 m
u=2 m f=50 mm f/5.6: DOF about 0.54 m
u=2 m f=50 mm f/11: DOF about 1.06 m
u=4 m f=50 mm f/2.8: DOF about 1.08 m
u=2 m f=100 mm f/2.8: DOF about 0.07 m
```

WHAT THE NUMBERS SHOW

Doubling the f-number doubles the depth (0.27 to 0.54 m). Doubling the distance quadruples it (0.27 to 1.08 m). Doubling the focal length at the same distance quarters it (0.27 to about 0.07 m). These match the proportions in the table above. Note the framing is not held constant in the last line: the subject would look twice as large.

Focus: Hyperfocal Distance

The article defines the hyperfocal distance as the distance beyond which all objects can be brought into acceptable focus, and gives maximum DOF. Focusing at that distance gives a DOF from half the hyperfocal distance to infinity. The commonly quoted formula H = f squared / (N c) + f was not in the part of the article I read, so treat it as unconfirmed (check).

Autofocus

From Wikipedia's Autofocus article: **active** systems measure the distance to the subject independently of the optical system (the article cites ultrasonic, infrared and time-of-flight methods); **passive** systems analyse the incoming image and need enough light and contrast.

PASSIVE METHOD	HOW IT WORKS	TRAITS
Phase detection	Splits the light into pairs of images and compares them	Fast; gives direction and distance to move; common in SLRs
Contrast detection	Adjusts focus until contrast peaks in a sensor field	Common in cameras without reflex mirrors; slower, no direction, harder for moving subjects

Focus modes: single-shot (Canon "One-Shot", Nikon "AF-S") halts on focus confirmation. Continuous (Canon "AI Servo", Nikon AF-C) predicts a moving subject's position from its speed and acceleration, which suits sports and action. The article's description is general; how current mirrorless cameras combine the methods was not covered in my reading (check).

> **A PRACTICAL CHOICE**
>
> For a still subject, use single-shot and lock focus. For a moving subject, use continuous. Which one is better for a given situation is advice of my own rather than from the article (check).

Not Yet Verified, and Sources

- **Sources.** Wikipedia articles Depth of field (read to about 100,000 of 112,055 characters; the last 12,000 were not read) and Autofocus (summary only).
- **Not confirmed.** The 0.03 mm circle of confusion for full-frame stills, the hyperfocal formula, accuracy of the approximation at close range, and how modern autofocus combines methods (all check).

Exercises

EXERCISE 1

Using the script with c = 0.03, find the approximate DOF for a 35 mm lens at 3 m (3000 mm) at f/4 and at f/8. How does the result compare with the rule that DOF grows in proportion to the f-number?

→ Solution

EXERCISE 2

A portrait is taken at 2 m with a 50 mm lens at f/2.8. Without running the script, say what the DOF becomes if you step back to 4 m (and do not change anything else), and give the reason. Then confirm with the script output in the chapter.

→ Solution

EXERCISE 3

Choose single-shot or continuous focus, and phase or contrast detection if you had the choice, for (a) a still landscape and (b) a child running. Give one sentence of reasoning each, based on the autofocus table.

→ Solution

QUICK REFERENCE

- **DOF:** about 2 u squared N c / f squared
- **More DOF:** higher f-number, greater distance, shorter focal length
- **Phase detection:** fast, gives direction
- **Contrast detection:** slower, no direction
- **Modes:** single-shot locks; continuous tracks
- **Check:** circle of confusion for stills, hyperfocal formula

COMING NEXT

Photography Fundamentals 4 turns to light: its direction, quality and the times of day that shape a picture.

Photography Fundamentals

Course 1 · Chapter 4 · Reading Light: Golden Hour and Colour Temperature

Light Is the Subject

Photography Fundamentals 1 to 3 dealt with how a camera records light. This chapter is about the light itself: when it is soft or harsh, warm or cool. The same scene can look completely different an hour apart.

Golden Hour

Wikipedia's Golden hour article describes it as the daytime period shortly after sunrise or before sunset, when daylight is redder and softer than when the sun is high. Photographers and cinematographers often call it the magic hour, though some cinematographers use "magic hour" for the time between sunset and nightfall when there is no direct sunlight.

DEFINITION OF GOLDEN HOUR	SUN ELEVATION
One group of sources	0 to 6 degrees, or 0 to 10 degrees, above the horizon
Another	4 degrees below to 6 degrees above
timeanddate.com (as cited by the article)	6 degrees below to 6 degrees above

The article gives three different definitions, so there is no single agreed answer. I have listed them side by side rather than choosing one.

Why the light looks the way it does

At a low angle the sunlight passes through more atmosphere. According to the article, this weakens direct light, so more illumination comes from the sky; contrast drops, shadows are less dark, and highlights are less likely to overexpose. More blue light is scattered, so the sunlight looks redder. Shadows are longer. Warm, diffuse light tends to suit landscapes and portraits.

BLUE HOUR

The blue hour comes just before golden hour at sunrise or just after it at sunset. The sun is below the horizon, roughly 3 to 10 degrees depending on the definition, the indirect sky light looks mostly blue

and shadows are soft.

THE "HOUR" IS NOT AN HOUR

The article says the period has no fixed length. It depends on season and latitude. Near the equator the sun climbs quickly and the period is under an hour; farther away it can last more than an hour, and at high latitudes in some seasons the sun may never reach 10 degrees, so golden hour can last all day. Check a sunrise and sunset table for your own location rather than assuming 60 minutes.

Colour Temperature

Colour temperature describes the colour of a light source by comparing it to an idealised black body, and is conventionally expressed in kelvins (K). The Color temperature article gives these example values:

SOURCE	COLOUR TEMPERATURE
Candle flame	1,850 K
Sunrise/sunset	1,850 K
Standard incandescent lamp	2,400 K
Horizon daylight	5,000 K
Vertical daylight	5,500 to 6,000 K
Overcast sky	6,500 K

The Golden hour article gives somewhat different figures: about 2,000 K shortly after sunrise or before sunset, about 3,500 K during golden hour and about 5,500 K at midday, and says altitude, latitude, season and weather shift them. The two pages do not agree exactly on sunrise and sunset (1,850 K against about 2,000 K), and I did not find out why (check).

WARM AND COOL RUN THE WRONG WAY ROUND

In artistic colour theory, colours over 5,000 K are called "cool" and 2,700 to 3,000 K "warm". The article says this is exactly the opposite of black-body radiation, where hotter objects glow bluer. So "warm light" means a low kelvin number.

The script below sorts the example values and labels them with a simple rule of my own (3,000 K or lower counts as warm-looking, 5,000 K or higher as cool-looking, anything between as in between). The article only names 2,700 to 3,000 K warm and above 5,000 K cool, so the in-between rule is a simplification (check). I ran it and the output is shown.

```
sources = {
    "Candle flame": 1850,
    "Sunrise/sunset": 1850,
    "Golden hour (typical)": 3500,
    "Standard incandescent lamp": 2400,
    "Midday sun (typical)": 5500,
    "Overcast sky": 6500,
}

def label(k):
    if k <= 3000:
        return "warm-looking"
    if k >= 5000:
        return "cool-looking"
    return "in between"

for name, k in sorted(sources.items(), key=lambda kv: kv[1]):
    print(f"{k:>5} K  {label(k):<13} {name}")
```

```
# Output
 1850 K  warm-looking  Candle flame
 1850 K  warm-looking  Sunrise/sunset
 2400 K  warm-looking  Standard incandescent lamp
 3500 K  in between    Golden hour (typical)
 5500 K  cool-looking  Midday sun (typical)
 6500 K  cool-looking  Overcast sky
```

WHAT TO TAKE FROM IT

The sun gets cooler-looking as it climbs, from about 1,850 to 3,500 K near the horizon to 5,500 K at midday, and an overcast sky is cooler still. Chapter 7 returns to this, because a camera has to be told which light it is looking at (white balance, check).

Not Yet Verified, and Sources

- **Sources.** Wikipedia articles Golden hour (photography) and Color temperature, both read through page summaries. The Color temperature page text is 134,346 characters and only the first 100,000 were covered.
- **Conflict not resolved.** Sunrise and sunset colour temperature differs between the two pages (1,850 K and about 2,000 K).
- **Not checked.** Midday daylight is not listed directly in the Color temperature table I saw; 5,500 K comes from the Golden hour page. The simplified warm/cool rule in the script is mine.

Exercises

EXERCISE 1

Look up sunrise and sunset times for your own location on one day in summer and one in winter. Estimate how long the sun spends below 6 degrees of elevation after sunrise, using whatever source you like, and say whether "golden hour" is longer in one season. Write down your source.

→ Solution

EXERCISE 2

Add three more sources of your own to the script (for example a cloudy day or a phone torch), looking up each kelvin value from a named source, and rerun it. Say which label each one gets and whether the label matches the article's warm and cool definition.

→ Solution

EXERCISE 3

Explain in three sentences why a photograph taken at 3,500 K golden-hour light looks warm even though 3,500 K is a higher number than a candle's 1,850 K. Use the "warm and cool run the wrong way round" box in your answer.

→ Solution

QUICK REFERENCE

- **Golden hour:** redder, softer light after sunrise or before sunset; defined variously as up to 6 or 10 degrees elevation
- **Blue hour:** sun roughly 3 to 10 degrees below the horizon
- **Colour temperature:** kelvins; warm-looking is low, cool-looking is high
- **Examples:** candle 1,850 K, midday about 5,500 K, overcast 6,500 K
- **Check:** sunrise figure conflict, the in-between rule

COMING NEXT

Photography Fundamentals 5 covers composition: how to arrange what is in the frame.

Composition

With exposure, lens, focus and light covered in Photography Fundamentals 1 to 4, the remaining question is where to put things in the frame. Composition is that choice. This chapter covers the best-known guideline, the rule of thirds, and a handful of other ideas from Wikipedia's Composition (visual arts) article, with a clear warning that all of them are guidelines, not laws.

The Rule of Thirds

Wikipedia's Rule of thirds article calls it a rule of thumb for composing designs, films, paintings and photographs. The guideline proposes that an image should be imagined as divided into nine equal parts, and key elements are placed along the lines or where they meet. The four intersections are sometimes called "power points" or "crash points".

PLACEMENT	EFFECT (PER THE ARTICLE)
Subject on a line or intersection	Avoids centring the subject
Horizon on the top or bottom line	Avoids splitting the frame in half
Moving or non-frontal subject	More open space is typically left in front of it

Where the idea comes from

The article says the term was first written down by John Thomas Smith in 1797 in *Remarks on Rural Scenery*, building on Joshua Reynolds's 1783 discussion of balancing light and dark. Smith favoured roughly a two-to-one ratio over an exact half.

A RULE OF THUMB, WITH CRITICS

The article reports that in 1845 George Field argued the rule was neither accurate nor universal and could produce monotonous work. It also cites a 2014 study (Amirshahi and colleagues) finding the rule "seems to play only a minor, if any, role" in large sets of high-quality photographs and paintings. I read these only in the article's summary of them, not the original papers (check).

The article lists the golden ratio only as a "See also" link and does not explain any relationship, so I make no claim about one (check).

Computing the Grid

The script below finds the four power points for an image size and the distance from any point to the nearest one. I ran it and the output is shown. It is my own illustration of the idea, not something from the article.

```
from math import hypot

def thirds(w, h):
    xs = (w / 3, 2 * w / 3)
    ys = (h / 3, 2 * h / 3)
    return [(x, y) for x in xs for y in ys]

def nearest(point, w, h):
    best = min(thirds(w, h), key=lambda p: hypot(p[0] - point[0], p[1] - point[1]))
    return best, hypot(best[0] - point[0], best[1] - point[1])

W, H = 6000, 4000
print("Power points:", thirds(W, H))
for name, pt in [("centre", (3000, 2000)), ("subject", (2100, 1300)), ("corner", (500, 5
    p, d = nearest(pt, W, H)
    print(f"{name:7} {pt} -> nearest {p[0]:.0f},{p[1]:.0f}, distance {d:.0f} px ({d / hy
```

```
# Output (first line shortened to two decimals)
Power points: [(2000.0, 1333.33), (2000.0, 2666.67), (4000.0, 1333.33), (4000.0, 2666.67
centre  (3000, 2000) -> nearest 2000,1333, distance 1202 px (16.7% of diagonal)
subject (2100, 1300) -> nearest 2000,1333, distance 105 px (1.5% of diagonal)
corner  (500, 500) -> nearest 2000,1333, distance 1716 px (23.8% of diagonal)
```

The first output line is shortened for display: the real line prints full floating-point numbers such as 1333.3333333333333. I renamed one label in the script after the run; the numbers are unchanged.

> **READING THE RESULT**

A dead-centre subject is the same distance (1202 px, 16.7% of the diagonal) from every power point, so no point is "nearest" in any meaningful sense; the script just returns the first one it checks. A subject placed 105 px from a power point is, to the eye, essentially on it. The distance is only a measure of how close you are, not of how good the picture is.

Other Compositional Ideas

From the Composition (visual arts) article, which covers art generally rather than photography only:

IDEA	WHAT THE ARTICLE SAYS
Balance	Works are pleasing when elements are "arranged in a balanced compositional way"; not defined further
Contrast	Value contrast creates the illusion of light; small, high-contrast elements can have as much impact as larger, duller ones
Movement	Compositions should encourage the eye to travel around the image rather than settle on one spot
Leading lines	Lines, literal or implied, guide the viewer's eye toward the subject or divide the composition
Symmetry	An option; an even number of subjects can create symmetries that look less natural in informal compositions
Negative space	The empty areas around, above and within a subject; the subject is positive space
Unity	Techniques aim to create a sense of unity within the work

NOT COVERED BY THE ARTICLE

I asked the article about emphasis, rhythm, proportion and framing. It does not name rhythm or proportion as principles, does not define framing (beyond a note about a central figure flanked by two others feeling friendly and comforting), and treats emphasis only as a centre of interest, usually off-centre. Photography courses often teach "frame within a frame"; I have not sourced that here (check).

Not Yet Verified, and Sources

- **Sources.** Wikipedia articles Rule of thirds and Composition (visual arts), both read through page summaries only.
- **Not read directly.** The Field (1845) argument and the 2014 study are reported second-hand through the article.
- **Not sourced.** The golden ratio link, the frame-within-a-frame idea, and any claim that thirds improves a photograph (all check).

Exercises

EXERCISE 1

Change the script to an image 4000 by 3000 pixels. List the four power points and find which one a subject at (1400, 900) is nearest, and how far away it is.

→ Solution

EXERCISE 2

Take any three of your own photographs. For each, draw the nine-part grid over it (most photo apps and phones can show one) and write down whether the main subject sits on a line, on an intersection or near the centre. Do the pictures that obey the rule look better to you? Give a reason, bearing in mind the critics' view.

→ Solution

EXERCISE 3

Match each description to one idea from the table: (a) a road that draws the viewer toward a distant point; (b) a large empty sky above a small figure; (c) a mirror-image layout; (d) a bright small object against a dark, large one. Then explain which one the rule of thirds tends to produce on its own.

→ Solution

QUICK REFERENCE

- **Rule of thirds:** imagine nine equal parts; use the lines and four intersections

- **First written:** John Thomas Smith, 1797 (per the article)
- **Caveat:** a rule of thumb; critics and a 2014 study say its role is small
- **Others:** balance, contrast, movement, leading lines, symmetry, negative space
- **Check:** golden ratio link, frame within a frame

COMING NEXT

Photography Fundamentals 6 returns to the camera: metering, exposure compensation and shooting modes.

Photography Fundamentals

Course 1 · Chapter 6 · Metering and Modes: Letting the Camera Help

Who Sets the Exposure?

Photography Fundamentals 1 showed that aperture, shutter speed and ISO trade against each other. In practice the camera measures the light and can set some or all of them for you. This chapter covers how it measures (metering), how you correct it (exposure compensation) and who chooses what in each shooting mode.

Metering Modes

Wikipedia's Metering mode article describes these ways of measuring a scene:

MODE	WHAT IT MEASURES (PER THE ARTICLE)
Multi-zone (evaluative, matrix, honeycomb)	Readings at several points combined; zone counts range from several to over a thousand; aims to reduce the need for exposure compensation and biases toward the autofocus point
Centre-weighted average	Concentrates on the central 60 to 80% of the scene and fades the influence of the edges
Partial (selective)	Roughly 10 to 15% of the frame; useful when very bright or dark edges would skew the reading
Spot	A very small area, about 1 to 5% of the viewfinder, by default at the centre; not influenced by other areas

WHEN THE METER IS FOOLED

The article says average metering, which weights the whole scene equally, can underexpose a snowy landscape "by 2 f-stops or more". A bright background can lead the meter to underexpose a backlit subject; spot metering on the subject exposes it correctly but overexposes the bright surroundings. These are the article's examples; other situations exist (check).

Exposure Compensation

Wikipedia's Exposure compensation article calls it a technique for adjusting the exposure indicated by an exposure meter, to account for factors that could make that reading less than ideal. Camera compensation is usually in EV, where one EV is one stop. Marks between whole numbers usually represent 1/3 stop, and positive values add exposure while negative values reduce it. The typical range is about two or three steps in either direction, and some cameras offer more (the article's examples are Canon EOS R6 Mark II at plus or minus 3 EV and Nikon Z 50 at plus or minus 5 EV; current specifications may differ, check).

Which setting changes depends on the mode: in aperture priority, compensation changes the shutter time; in shutter priority, it changes the aperture. The article says meters are calibrated for typical scenes, so a predominantly light subject (its example is a white horse) often ends up underexposed and needs positive compensation, while a predominantly dark subject needs negative compensation.

Shooting Modes

MODE	YOU SET	CAMERA SETS
Manual	Aperture and shutter speed	Nothing
Aperture priority (A or Av)	Aperture	Shutter speed
Shutter priority (S, or Tv for "time value")	Shutter speed	Aperture
Program	Neither	Both

According to the Shutter priority article, "S" is common on Nikon, Minolta, Sony and others, while "Tv" is used by Canon, Pentax and Leica. The Aperture priority article gives A or Av. The abbreviations for program and manual (P and M) were not on the pages I read, so they are from my own knowledge (check). I also did not find a page covering these modes together; the Automatic exposure page I tried returned an error.

Seeing Compensation Work

The script below simulates aperture priority: the meter gives an EV, you fix the aperture, and the camera computes the shutter time from EV = log2(N squared / t), rearranged as t = N squared /

2 to the power EV. Positive compensation asks for more light, so the camera uses a lower EV, meaning a longer time. This is my own illustration, and the sign convention is the part I would check against a real camera (check). I ran it and the output is shown.

```
from math import log2

def shutter_time(n, ev):
    """Time in seconds that gives exposure value ev at f-number n."""
    return n * n / 2 ** ev

def show(label, t):
    print(f"{label:<28} 1/{1 / t:.0f} s")

metered_ev = 15  # a bright scene at ISO 100, as the meter reads it
n = 8
base = shutter_time(n, metered_ev)
show("Meter says (EV 15), f/8", base)
for comp in (+1, +2, -1):
    ev_used = metered_ev - comp  # + compensation = more light = lower EV setting
    show(f"Compensation {comp:+d} EV", shutter_time(n, ev_used))
```

```
# Output
Meter says (EV 15), f/8      1/512 s
Compensation +1 EV           1/256 s
Compensation +2 EV           1/128 s
Compensation -1 EV           1/1024 s
```

READING THE OUTPUT

Each +1 EV halves the shutter speed number, doubling the time, which is one stop more light, as Chapter 1 predicts. The meter's 1/512 s is the exact result; a real camera would round to a nearby standard speed such as 1/500 s. In the snow example, the article's "2 f-stops or more" underexposure corresponds to the +2 line, where the camera is told to let in four times as much light.

Not Yet Verified, and Sources

- **Sources.** Wikipedia articles Metering mode, Exposure compensation, Shutter priority and Aperture priority, all read through page summaries. The Automatic exposure page returned

an error and was not read.

- **Not on the pages read.** The 18% grey assumption behind meters (the Metering mode page does not mention it), the P and M abbreviations, the real sign convention on any given camera, and current camera specifications.
- **Not tested.** I did not test any of this on a physical camera.

Exercises

EXERCISE 1

Adapt the script for f/4 with a metered EV of 12 and compensation of +1 and -2. Give each shutter time and say which standard speed from Chapter 1 is nearest.

→ Solution

EXERCISE 2

For each scene, name the metering mode you would pick and say whether you would add positive or negative compensation, with one sentence of reason: (a) a snowy field, (b) a person standing in front of a bright window, (c) a dark-coloured subject filling the frame.

→ Solution

EXERCISE 3

Pick the mode (manual, aperture priority, shutter priority or program) you would choose for (a) a blurred background in a portrait, (b) freezing a moving subject, (c) a quick snapshot with no time to think, and say what the camera sets in each case.

→ Solution

QUICK REFERENCE

- **Metering:** multi-zone, centre-weighted, partial, spot
- **Compensation:** in EV; 1 EV = 1 stop; positive adds exposure
- **Aperture priority:** you set aperture, camera sets shutter

- **Shutter priority:** you set shutter, camera sets aperture
- **Check:** grey assumption, P and M abbreviations, sign convention

COMING NEXT

Photography Fundamentals 7 covers colour and white balance, using the colour temperature figures from Chapter 4.

Photography Fundamentals

Course 1 · Chapter 7 · White Balance: Getting Colour Right

The Problem

Photography Fundamentals 4 showed that light sources differ widely in colour temperature, from about 1,850 K for a candle to 6,500 K for an overcast sky. Our eyes and brain largely adjust to this; a camera does not. White balance is how the picture is corrected so that neutral colours, such as a white wall, look neutral.

Wikipedia's Color balance article describes colour balance as the global adjustment of colour intensities (typically red, green and blue) so that neutral colours render correctly, with white balance the most common kind. It makes a white object look white rather than tinted. The article gives three reasons it is needed: camera sensors do not respond like the human eye, display properties must be accounted for, and shooting conditions often differ from viewing conditions.

Camera Settings

The article says cameras may offer manual lighting selection, automatic white balance or custom white balance. Its only worked example of presets is one camera model, the Nikon Z 50:

LIGHT	APPROXIMATE SETTING (NIKON Z 50, PER THE ARTICLE)
Incandescent	about 3,000 K
Direct sunlight	about 5,200 K
Flash	about 5,400 K
Cloudy	about 6,000 K
Shade	about 8,000 K

Users can also set any value from 2,500 to 10,000 K on that camera. Other makers' presets and values differ, and I did not check them (check). Notice that these are close to Chapter 4's values but not the same: 3,000 K for incandescent against 2,400 K for a standard lamp, and 6,000 K for cloudy against 6,500 K for overcast. A preset is a nominal setting, not a measurement.

CUSTOM WHITE BALANCE

The article says that on some cameras you can point the camera at a gray card or other neutral object and press a button to capture the ambient light, so the camera sets the correct balance.

Automatic White Balance and the Gray World Idea

The article says the algorithms behind automatic white balance perform generalised chromatic adaptation but does not describe them in detail; it mentions estimation approaches such as Retinex, neural networks and Bayesian methods. It does not discuss the "gray world" assumption (and the Wikipedia page I tried for it returned an error), so the following is my own illustration of a well-known simple idea, not the method any camera uses (check).

The gray world idea assumes that the average colour of a whole scene is neutral grey. If the red average is too high, scale red down, and scale blue up if it is too low. The script below does that and I ran it, with a made-up scene lit by warm light.

```
def gray_world(pixels):
    """Scale R, G, B so their averages match the overall average."""
    n = len(pixels)
    avg = [sum(p[i] for p in pixels) / n for i in range(3)]
    grey = sum(avg) / 3
    gains = [grey / a for a in avg]
    fixed = [tuple(min(255, round(p[i] * gains[i])) for i in range(3)) for p in pixels]
    return gains, fixed

# A scene lit by warm light: everything leans red.
scene = [(200, 150, 100), (160, 120, 80), (240, 180, 120), (100, 75, 50)]
gains, fixed = gray_world(scene)
print("gains (R, G, B):", [round(g, 2) for g in gains])
for before, after in zip(scene, fixed):
    print(before, "->", after)
```

```
# Output
gains (R, G, B): [0.75, 1.0, 1.5]
(200, 150, 100) -> (150, 150, 150)
(160, 120, 80) -> (120, 120, 120)
```

```
(240, 180, 120) -> (180, 180, 180)
(100, 75, 50) -> (75, 75, 75)
```

TOO GOOD TO BE TRUE

Every pixel came out a perfect grey. That is because I made the scene by tinting greys with a fixed warm cast, so the assumption holds exactly. Real scenes are not like this, and Exercise 1 shows what happens when the assumption is wrong. Also, real cameras work on linear sensor data and more carefully, so do not treat this as how a photo app works (check).

Raw Files

The article says getting the balance right at capture is advantageous. If balancing has to happen later, adjusting the raw image data tends to distort chromatic colours less than adjusting in monitor RGB. What a raw file is gets its own treatment in Photography Fundamentals 8.

Not Yet Verified, and Sources

- **Sources.** Wikipedia article Color balance, read through a page summary. The Gray world page I tried returned an error and was not read.
- **Not on the page read.** The gray world assumption and my script (my own illustration), other makers' presets, and mired shifts (check).
- **Not tested.** I did not test the script on a real image.

Exercises

EXERCISE 1

Run the script on a scene with a large strongly red object: `[(200, 40, 40), (100, 100, 100), (120, 120, 120), (80, 80, 80)]`. What happens to the three grey pixels, and what does that tell you about the gray world assumption?

→ Solution

EXERCISE 2

Using the table, which preset would you try for (a) a living room under an ordinary lamp, (b) a sunny afternoon, (c) a photo of a shaded garden path on a bright day? If the result looks too blue or too orange, which way would you move the kelvin setting, and why?

→ Solution

EXERCISE 3

Run the script on a cool-cast scene: `[(90, 120, 200), (60, 80, 140)]`. Give the gains, say which colour is boosted and which reduced, and explain what light source might have caused such a cast.

→ Solution

QUICK REFERENCE

- **White balance:** adjusting colour so neutrals look neutral
- **Camera options:** manual selection, automatic, custom (grey card)
- **Example presets (one model):** 3,000 / 5,200 / 5,400 / 6,000 / 8,000 K
- **Gray world:** my illustration only; fails with large coloured areas
- **Check:** other makers' presets, real algorithms

COMING NEXT

Photography Fundamentals 8 covers raw files, JPEG and basic editing.

What the Camera Saves

Most cameras let you save a picture as a JPEG, a raw file, or both. Photography Fundamentals 7 mentioned that setting white balance later is easier on raw data; this chapter explains the difference, and how to check exposure with a histogram.

Raw and JPEG Compared

Wikipedia's Raw image format article says a camera raw file "contains unprocessed data straight from a digital camera", which software (or the camera) later converts into a viewable picture. The JPEG article calls JPEG a lossy compression method: some original information is lost and cannot be restored.

POINT	RAW	JPEG
Bit depth	Typically 12 or 14 bits per channel (about 4,096 to 16,384 shades)	8 bits per channel (24-bit colour)
Compression	Typically lossless or high-quality lossy	Lossy; adjustable quality trade-off (a 0 to 100 scale in common encoders); typically about 10:1
File size	Typically 2 to 6 times larger than a JPEG	Smaller
White balance	Can be set to any value later	Baked in; not just a metadata choice (check)
Editing	Large corrections show fewer artifacts; changes are non-destructive	Quality drops each time it is re-saved
Opening	Needs a conversion step and possibly specialised software	Opens almost anywhere

RAW IS NOT A SINGLE FORMAT

The article says manufacturers use their own, typically undocumented formats, and several encrypt parts of their files. Adobe's DNG is an open, royalty-free alternative that extends TIFF 6.0. Whether your software supports your camera's raw files depends on the camera and the software (check).

Counting Shades

The script below turns bits per channel into the number of shades per channel and the number of possible colours (three channels). I ran it and the output is shown. The numbers are simply powers of two; the article's 4,096 to 16,384 shades for 12 and 14 bits agree.

```
for bits in (8, 12, 14):
    print(f"{bits:>2} bits per channel: {2 ** bits:>6} shades, {2 ** (3 * bits):,} colou
```

```
# Output
 8 bits per channel:    256 shades, 16,777,216 colours
12 bits per channel:   4096 shades, 68,719,476,736 colours
14 bits per channel:  16384 shades, 4,398,046,511,104 colours
```

MORE SHADES IS NOT MORE DETAIL

Extra bit depth gives smoother tones and more room to brighten or darken without visible steps. It does not add resolution or sharpness. That is my own plain-language summary, not a sentence from the article (check).

JPEG Habits

The JPEG article says JPEG is not well suited to files that will undergo multiple edits, because quality drops each time the file is recompressed, and recommends editing in a lossless format and producing the JPEG at the end. It describes the resulting quality loss at about 10:1 as perceptible but widely accepted as tolerable. It also notes chroma subsampling, most commonly 4:2:0, which halves colour-information resolution both horizontally and vertically.

The Histogram

A histogram, per Wikipedia's article, plots tonal values on the horizontal axis, dark on the left and light on the right, with the number of pixels at each tone on the vertical axis. A very dark image has most of its data on the left and centre; a very bright one has it on the right and centre. Photographers use it to see whether detail has been lost to blown-out highlights or blacked-out shadows (clipping). The article does not describe what clipping looks like; it appears as pile-ups at the far ends, which is my own description (check). The article also warns that the histogram is less useful for raw files, because the displayed image's dynamic range may only approximate the raw file's.

The script builds a text histogram of 16 invented pixel brightness values (0 to 255) in eight bins and counts values at the extremes. The "clipped" test here, exactly 0 or exactly 255, is a simplification of my own. I ran it.

```
def histogram(values, bins=8, top=255):
    counts = [0] * bins
    for v in values:
        counts[min(bins - 1, v * bins // (top + 1))] += 1
    return counts

pixels = [0, 0, 5, 30, 60, 90, 120, 128, 140, 180, 200, 230, 255, 255, 255, 255]
h = histogram(pixels)
for i, c in enumerate(h):
    print(f"{i * 32:>3}-{i * 32 + 31:<3} {'#' * c}")
print("clipped shadows:", pixels.count(0), "clipped highlights:", pixels.count(255))
```

```
# Output
  0-31  ####
 32-63  #
 64-95  #
 96-127 #
128-159 ##
160-191 #
192-223 #
224-255 #####
clipped shadows: 2 clipped highlights: 4
```

READING THE EXAMPLE

The tallest bars are at the two ends: four pixels in the darkest bin and five in the brightest, with four exactly at 255. This mimics a high-contrast scene where highlights have been blown out. Reducing exposure (Photography Fundamentals 6's negative compensation) would shift the pile-up away from the right edge.

Not Yet Verified, and Sources

- **Sources.** Wikipedia articles Raw image format (read to about 100,000 of 102,213 characters; the last 2,213 were not read), JPEG (about 100,000 of 221,037 characters; the rest was not read) and Histogram (photography). All were read through page summaries.
- **Not on the pages read.** Whether a JPEG's white balance is truly fixed, the visual signature of clipping, and the idea that bit depth is not detail (my summaries; check).
- **Not tested.** I did not open a real raw file or compare real files.

Exercises

EXERCISE 1

Add 10 and 16 bits to the first script. Give the number of shades per channel for each, and say how many times more shades 14 bits gives than 8 bits.

→ Solution

EXERCISE 2

For each job choose raw, JPEG, or both, with a one-sentence reason from the comparison table: (a) a rushed set of snapshots to send straight to a friend, (b) a difficult high-contrast scene you expect to edit heavily, (c) a shoot where card space is very limited.

→ Solution

EXERCISE 3

Run the histogram script on `[100, 110, 120, 130, 140, 150, 160, 170]`. Give the bar heights, describe the shape, and say what kind of picture it suggests.

→ Solution

QUICK REFERENCE

- **Raw:** unprocessed data, 12 or 14 bits, bigger files, flexible edits
- **JPEG:** lossy, 8 bits, small, degrades on repeated saves
- **DNG:** open raw format from Adobe
- **Histogram:** dark left, light right; look for pile-ups at the ends
- **Check:** clipping appearance, bit depth versus detail

COMING NEXT

Photography Fundamentals 9 looks at genres of photography and what each demands of the settings you now know.

Same Tools, Different Choices

You now have the tools: exposure (Photography Fundamentals 1), lenses (2), depth of field and focus (3), light (4), composition (5), metering and modes (6), white balance (7) and files (8). A photographic genre is mostly a typical set of choices among them. This chapter takes four genres from Wikipedia's articles and shows which earlier chapter each choice comes from. These are tendencies described by those articles, not rules.

Portrait

Wikipedia's Portrait photography article says portraiture aims to capture a person's or group's personality through lighting, backdrops and poses.

- **Lens.** Fast, moderate-focal-length telephoto lenses are typical. For head-and-shoulders shots, the classic lengths are 75 to 135 mm on 135 film (full frame), which the page describes as about 1.5 to 2.5 times a normal lens. Short focal lengths can exaggerate the nose and shrink the ears, which the page considers unflattering. (Chapter 2: a normal lens on full frame is about 43 to 50 mm.)
- **Aperture.** A wide aperture gives shallow depth of field, which isolates the subject. Stopping down one or two stops helps keep the whole face sharp when focusing on the eyes. (Chapters 1 and 3.)
- **Light.** Three-point lighting uses a key, a fill and a back light, with the key about 30 to 60 degrees from the camera. High-key is mostly shadow-free with a bright background; low-key lights only part of the subject, typically with one light. Window light is best in early morning and late afternoon, and a reflector can even out contrast. (Chapter 4.)

Landscape

The Landscape photography article defines it as capturing the world's outdoor spaces, usually nature but sometimes including human-made features.

- **Aperture.** The whole scene usually needs to be sharp, so a small aperture is typical, with f/11 to f/13 described as best for clarity and depth of field. A small aperture admits less light, so a slower shutter is often needed, which can blur moving leaves or water. (Chapters 1 and 3.)
- **Lens.** A wide-angle lens is generally preferred for wide open spaces; a telephoto can isolate a smaller area at a distance. (Chapter 2.)
- **Support.** A tripod is "widely regarded as essential"; a timer, remote or cable release avoids vibration. (Chapter 1's shutter-speed rule of thumb applies when hand-holding.)
- **Light.** Natural ambient light, with dawn, dusk, sunrise and golden hour among the best times. (Chapter 4.)

Street

The Street photography article describes it as photography for art or inquiry that captures unmediated chance encounters and random incidents in public places, often aiming for a decisive or poignant moment. It does not require a street or even people.

- **Equipment.** Classically shot with wider-angle lenses (the article gives 35 mm as an example) in urban environments. It credits the compactness and bright viewfinder of the Leica with helping photographers move through busy streets. (Chapter 2.)
- **Candid nature.** Generally unposed, usually with unaware subjects, though some photographers interact with strangers and take posed street portraits.

> **CHECK THE LAW AND THE ETHICS**
>
> The article says photographing strangers in public without consent is legal in most countries that protect freedom of expression, but is controversial, and limits often apply to how images are used. Its examples differ by country: Quebec generally requires consent before publication; Germany has a right to one's own picture, so publication usually needs permission; Japan needs permission to photograph and publish recognisable people; US courts have generally treated street photography as protected speech. Critics raise privacy and autonomy concerns. This is a summary of an encyclopedia article, not legal advice, and laws change (check). Look up the rules where you actually shoot.

Close-up and Macro

The Macro photography article says that strictly a macro photograph has an optical reproduction ratio of 1:1 or greater, meaning the image on the sensor is life-size or larger. It gives typical ranges: close-up 0.1 to 0.5 times, extreme close-up 0.5 to 1.0 times, macro 1.0 to 35 times, and notes many lenses marketed as macro are technically close-up lenses.

- **Depth of field.** Extremely small when focusing on close objects, so a small aperture is often needed, which means a slow shutter, strong light or a high ISO. (Chapter 3.)
- **Extension tubes and bellows.** Magnification m = d / F, where d is the extension and F the focal length.
- **Exposure.** The effective f-stop is f times (1 + m), so you lose light at close range.
- **Close-up (diopter) lenses.** Power in diopters is 1 divided by the focal length in metres.
- **Other.** Telephoto macro lenses of about 100 to 200 mm give more working distance; focus stacking combines shots at different focus distances; ring flashes and diffusers light close subjects.

The script applies those three formulas. The light-loss column, log2 of (1 + m) squared in stops, is my own application of Chapter 1's stop definition to the article's formula (check). I ran it and the output is shown.

```
from math import log2

def magnification(extension, focal_length):
    return extension / focal_length

def effective_f(n, m):
    return n * (1 + m)

def diopters(focal_length_m):
    return 1 / focal_length_m

for ext in (0, 25, 50, 100):
    m = magnification(ext, 100)
    stops = log2((1 + m) ** 2)
    print(f"100 mm + {ext:>3} mm extension: m = {m:.2f}, f/8 acts like f/{effective_f(8,
print("Close-up lens, 0.5 m focal length:", diopters(0.5), "diopters")
```

```
# Output
100 mm +   0 mm extension: m = 0.00, f/8 acts like f/8.0, light loss 0.00 stops
```

```
100 mm +  25 mm extension: m = 0.25, f/8 acts like f/10.0, light loss 0.64 stops
100 mm +  50 mm extension: m = 0.50, f/8 acts like f/12.0, light loss 1.17 stops
100 mm + 100 mm extension: m = 1.00, f/8 acts like f/16.0, light loss 2.00 stops
Close-up lens, 0.5 m focal length: 2.0 diopters
```

LIFE SIZE COSTS TWO STOPS

At m = 1 (life size) the effective aperture is twice the marked one, f/8 acting like f/16, which per Chapter 1's table is two full stops. That agrees with the formula, but I did not test it with a real lens and meter, and cameras that meter through the lens may compensate automatically (check).

Not Yet Verified, and Sources

- **Sources.** Wikipedia articles Portrait photography, Landscape photography, Street photography (read to about 100,000 of 112,846 characters) and Macro photography (about 100,000 of 110,609). All were read through page summaries; the unread tails were not checked.
- **Not on the pages read.** Zone focusing, the stops-lost conversion in the script, automatic compensation by cameras, and any current law (all check).
- **Not tested.** I did not test any technique with a real camera.

Exercises

EXERCISE 1

A 50 mm lens at f/4 is used with a 25 mm extension tube. Find the magnification, the effective f-number and the light lost in stops, using the script's formulas.

→ Solution

EXERCISE 2

For each scene, name the genre from this chapter and suggest a focal length range, an aperture and a time of day, justifying each by an earlier chapter: (a) a hillside valley at sunrise, (b) a head-and-shoulders portrait by a window, (c) a stranger crossing a busy road.

→ Solution

EXERCISE 3

A close-up lens is rated 3 diopters. What is its focal length in metres? Then a 200 mm lens gets a 100 mm extension: what is the magnification, and does it reach the strict macro definition?

→ Solution

QUICK REFERENCE

- **Portrait:** 75 to 135 mm full frame, wide aperture, soft side or window light
- **Landscape:** wide angle, f/11 to f/13, tripod, dawn or dusk light
- **Street:** wide angle such as 35 mm, candid; check local law
- **Macro:** 1:1 or greater; m = d / F; effective f = f times (1 + m)
- **Check:** law, stops formula, automatic compensation

COMING NEXT

Photography Fundamentals 10 is a capstone: planning, shooting and reviewing a photo walk using everything in this course.

Photography Fundamentals

Course 1 · Chapter 10 · Capstone: A Photo Walk from Plan to Review

The Project

This final chapter has no new theory. You plan a short photo walk, shoot it, and review the results using the nine earlier chapters. The aim is a set of about ten pictures and a short written review of what worked. Facts here are recalled from earlier chapters, which cite their own sources; where I add something new it is marked (check).

Step 1: Plan

DECIDE	PROMPT	FROM
When	Pick a time near sunrise or sunset if you can, and look up the actual times for your location; golden hour has no fixed length	Chapter 4
What	Choose two or three genres to try, such as landscape, street, portrait or close-up	Chapter 9
Kit	Which lens or focal lengths, and whether you need a support	Chapters 2 and 9
File type	Raw, JPEG or both, depending on card space and editing plans	Chapter 8
Mode	Aperture priority for depth of field, shutter priority for movement, or manual	Chapter 6

PEOPLE AND PLACES

If you photograph strangers, remember Chapter 9: the rules differ by country and change over time, and publishing a picture can be treated differently from taking it. Read the rules where you shoot (check). Also keep to the property owner's rules, which I have not researched here (check).

Step 2: Shoot

- **Light first.** Look at the direction and softness of the light before choosing the frame (Chapter 4).
- **Frame.** Try the rule of thirds, then try breaking it on purpose (Chapter 5).
- **Check the exposure.** Look at the histogram for pile-ups at either end, and use compensation if a snowy or dark scene fools the meter (Chapters 6 and 8).
- **Set white balance.** Pick a preset or use a grey card if the colour looks wrong, or fix it later if you shoot raw (Chapter 7).
- **Keep a log.** Note aperture, shutter speed and ISO for each shot you want to learn from. Many cameras store this automatically as metadata, but I have not checked which fields your camera keeps (check).

Step 3: Review with a Script

To compare shots taken in different light, put them on one scale. The script converts each log entry to EV at ISO 100, using Chapter 1's relation EV(S) = EV(100) + log2(S/100). The four entries are invented examples. I ran it and the output is shown.

```
from math import log2

shots = [
    ("hillside at sunrise", 11, 1/60, 100),
    ("market stall",         4, 1/250, 800),
    ("window portrait",    2.8, 1/125, 400),
    ("bright street",        8, 1/500, 100),
]

def ev100(n, t, iso):
    """EV at ISO 100: EV at the shot's ISO minus log2(ISO/100)."""
    return log2(n * n / t) - log2(iso / 100)

for name, n, t, iso in shots:
    print(f"{name:<20} f/{n:<4} 1/{round(1 / t):<4} ISO {iso:<4} EV100 {ev100(n, t, iso)
```

```
# Output
hillside at sunrise  f/11   1/60   ISO 100  EV100 12.83
market stall         f/4    1/250  ISO 800  EV100  8.97
```

```
window portrait      f/2.8  1/125  ISO 400  EV100  7.94
bright street        f/8    1/500  ISO 100  EV100 14.97
```

WHAT THE NUMBERS SUGGEST

The brightest scene is the street (EV100 near 15), which matches Chapter 1's table where full or slightly hazy sunlight is 15. The portrait, at about 8, sits near the table's bright street scenes and a little above home interiors (5 to 7), plausible for window light. The sunrise hillside, at about 13, falls in the range of cloudy-bright scenes. These are the table's rough categories, not exact (check).

Step 4: Write the Review

For each of your best three and worst three pictures, answer in one line each: What was the light? Did exposure match what you wanted? Was the focus where you meant it? Where did the subject sit in the frame? Was the colour right? Which one setting would you change next time? Keeping the review short makes you more likely to do it.

COURSE COMPLETE

You have worked through the whole sequence: exposure, lenses and sensor size, depth of field and focus, light and colour temperature, composition, metering and modes, white balance, files and histograms, genres, and a walk of your own. The best next step is more walks. Keep each log and compare it with the last one.

Not Yet Verified, and Sources

- **Sources.** This chapter relies on the earlier chapters, each of which lists its own Wikipedia sources and caveats. No new sources were read for it.
- **Not checked.** Local legal rules and property rules, which metadata fields your camera stores, and the match between the invented example shots and real scenes.
- **Not tested.** I did not run a real photo walk.

Exercises

EXERCISE 1

Add a fifth entry to the script: f/5.6, 1/125 s, ISO 200. Work out its EV at ISO 100 by hand first, then check by running it, and say which of Chapter 1's example scenes it is closest to.

→ Solution

EXERCISE 2

Write a one-page plan for your own walk using the Step 1 table: date and time (with real sunrise or sunset times), two or three genres, lens, file type, mode, and one rule you will test, such as shooting every frame off-centre.

→ Solution

EXERCISE 3

After the walk, write the Step 4 review for your best three and worst three pictures, and finish with a list of three settings or habits to change next time, each tied to a chapter in this course.

→ Solution

QUICK REFERENCE

- **Plan:** time, genres, kit, file type, mode
- **Shoot:** light, frame, histogram, white balance, log
- **Review:** EV100 for comparison; one line per picture
- **EV(S):** EV(100) plus log2(S/100)
- **Check:** local rules, camera metadata