Antelope

Photograph a 1m × 1m antelope at 100m

Required exposure = .2 lm sec/m^2 = .2 lux-s

Exposure time ≤ .2 sec on a sunny day

The frame size is 24 × 36 mm. Putting the 1m dimension onto the 24 mm dimension requires a magnification:

$$m = -24\text{mm}/1\text{m} = S_2/S_1$$

$$S_1 = -100 \text{ m}$$

$$S_2 = 2400 \text{ mm} = 2.4 \text{ m}$$

$$\frac{1}{S_2} = \frac{1}{S_1} + \frac{1}{f} \qquad f = 2345 \text{ mm}$$

Lets use a slightly shorter focal length and pick 2000 mm as being "commercially available."

$$\boxed{f = 2000 \text{ mm}}$$

$$S_2 = 2041 \text{ mm}$$

$$m = \frac{S_2}{S_1} = -.0204$$

and the antelope will be 20.4 mm high on the film

On a sunny day, the scene illumanance is about

$$E_v = 1.2 \times 10^5 \ lx \quad (lm/m^2)$$

With a scene reflectivity of ρ, the luminous exitance is

$$M_v = \rho \, E_v$$

and a lambertian reflector will produce a luminance

$$L_v = \rho \, E_v / \pi = \rho \; 3.82 \times 10^4 \ lm/m^2 \, sr \quad (nt)$$

Now assume the "normal" scene and $\rho = .18$

$$\boxed{L_v = 6875 \ nt}^{*} \quad (lm/m^2 \, sr)$$

The required exposure is .2 lux-s at .02 sec.
The image illuminance must therefore be

$$E_v' \geq (.2 \ lm \ sec/m^2)/(.02 \ sec)$$

$$\boxed{E_v' \geq 10 \ lm/m^2 = 10 \ lx}$$

* The unit nit or nt equals a $lm/m^2 \, sr$

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Using the camera equation:

$$E_v' = \frac{\pi L_v}{4 (f/\#)^2 (1-m)^2}$$

$$(f/\#)^2 = \frac{\pi L_v}{4 E_v' (1-m)^2}$$

$L_v = 6875$ nt
($lm/m^2 sr$)

$E_v' > 10$ lx
(lm/m^2)

$m = -.02$

$$(f/\#)^2 < 519$$

$$\boxed{f/\# < 22.78}$$

We therefore need an f/22 2000 mm lens.

- This is a 90$^+$ mm diameter lens aperture.

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