Appendix B:
Formulas, Units, and Worked Calculations

A wrong unit can spoil a sound calculation as thoroughly as a wrong measurement can spoil a welding repair. I keep these formulas and conversions handy when I want to check a result myself.

Units Worth Keeping Close

Our weather reports use miles per hour, but the force calculation uses meters and seconds. I convert the inputs first and round the finished result.

Quantity	Conversion	Why it matters
Wind speed	1 mph = 0.44704 m/s	Use m/s before squaring wind speed.
Body mass	1 lb = 0.45359237 kg	Mass does not replace projected area.
Area	1 ft^2 = 0.09290304 m^2	A must agree with the coefficient's area convention.
Force	1 N ≈ 0.224809 lbf	Newtons and pounds-force describe force.
Pressure	1 Pa = 1 N/m^2	Dynamic pressure is force per unit area.
Horse height	1 hand = 0.1016 m	A familiar height measure, not a wind-force input.

Unit conversions used in the worked examples. A pound of mass (lb) and a pound-force (lbf) are not interchangeable.

The Push of Moving Air

Dynamic pressure depends on the air's density and the square of its speed relative to the animal:

$$q = \tfrac{1}{2}\rho V^2$$

Here q is dynamic pressure in pascals, ρ is air density in kilograms per cubic meter, and V is relative airspeed in meters per second.

For conditional drag along the relative airflow, I use:

$$F_D = qC_DA = \tfrac{1}{2}\rho V^2 C_D A$$

F_D is force in newtons, A is the projected area in square meters, and C_D is the dimensionless drag coefficient that goes with the chosen area convention. An outline alone does not supply that coefficient.

Throughout these examples I use ρ = 1.225 kg/m^3. The assumed C_D values of 0.60, 0.80, and 1.00 are for arithmetic comparisons; they have not been measured for these animals.

For comparisons between differently sized physical models, Reynolds number is also useful:

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$$Re = \rho V L / \mu$$

Re is Reynolds number, L is a stated characteristic length in meters, and μ is dynamic viscosity in pascal-seconds. It does not provide a drag coefficient by itself.

A Holstein Cow and a Fifteen-Mile-Per-Hour Wind

For the Holstein cow at standard size, the unrounded broadside area is 2.1940905 m². In a 15-mph relative wind, with C_D assumed to be 0.80, the calculation goes like this:

First, 15 mph becomes 6.7056 m/s. At the reference air density, q = 27.5411 Pa. Multiplying by the projected area and the assumed coefficient gives:

$$F_D = \tfrac{1}{2}(1.225)(6.7056)^2(0.80)(2.1940905) \approx 48.34 \text{ N}$$

That is 10.87 pounds-force after conversion. This table sets out each step, including the inputs, so a reader can check my work rather than take my word for it.

Step	Input or operation	Result
Relative wind speed	15 × 0.44704	6.7056 m/s
Air density	Chosen reference value	1.225 kg/m³
Dynamic pressure	½ × 1.225 × (6.7056)²	27.54 Pa
Cow broadside area	Selected 90° view at standard size	2.1941 m²
Drag coefficient	Hypothetical assumption	0.80
Calculated force	27.5411 × 0.80 × 2.1940905	48.34 N
Force converted	48.34 × 0.224809	10.87 lbf

Worked broadside calculation for the representative Holstein cow in a 15-mph relative wind. Air density is fixed at 1.225 kg/m³ and C_D = 0.80 is hypothetical; no force was measured on a living cow.

When the Animal Is Moving, Too

If the cow walks north at 3 mph while a west wind moves east at 15 mph, I subtract her walking velocity from the wind velocity. The resulting air velocity relative to her is 15 mph east and 3 mph south:

$$V_r = \sqrt{(15^2 + 3^2)} = 15.30 \text{ mph}$$

$$\theta = \tan^{-1}(3 / 15) \approx 11.3^\circ \text{ from pure broadside}$$

No assumed coefficient is needed for those two results; the stability questions belong to Chapter 13.

A force estimate at that new angle still needs a matching projected area and coefficient.

Turning the Body and Changing Its Size

The companion program changes the viewing direction in five-degree steps. A separate uniform scale setting enlarges or reduces the whole animal without changing its proportions.

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For a uniform linear scale factor s, the projected area changes according to:

$$A_{new} = s^2 A_{original}$$

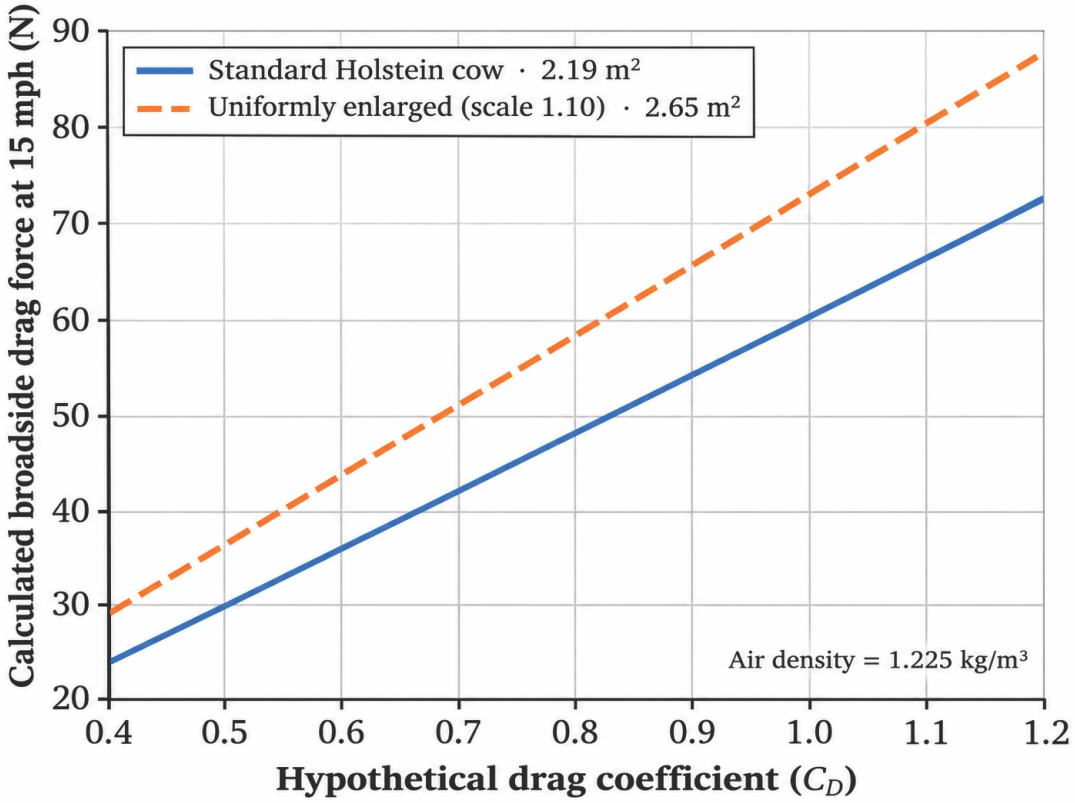
For example, s = 1.10 gives 1.21 times the original area. With the same wind and coefficient, the calculated force also rises by 21 percent. That result is a rule of geometry, not a prediction of how a living animal grows.

What Changes When the Coefficient Changes

This table shows what happens when I change the assumed coefficient, uniform size, or wind speed while leaving the remaining inputs fixed.

Holstein-cow broadside case	Uniform scale	Assumed C_D	Force (N)
15 mph; standard size	1.00	0.60	36.26
15 mph; standard size	1.00	0.80	48.34
15 mph; standard size	1.00	1.00	60.43
15 mph; 10% larger	1.10	0.80	58.49
15 mph; 10% smaller	0.90	0.80	39.16
25 mph; standard size	1.00	0.80	134.28

Table B.3 Conditional drag calculations using the same Holstein-cow geometry, 1.225 kg/m³ air density, and the stated changes to wind, coefficient, or uniform size. They are arithmetic sensitivity cases, not observed animal forces or confidence limits.



Illustrative broadside drag force versus hypothetical coefficient for the representative Holstein cow at 15 mph,

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showing the standard size and a uniformly enlarged model (scale 1.10).

Checking a Result

As a check on the companion program, the Holstein cow at standard size and 15 mph, with $\rho = 1.225$ kg/m³ and $C_D = 0.80$, should give 2.194 m² and 48.34 N broadside. At 25 mph it should give 134.28 N; with scale 1.10 at 15 mph it should give 58.49 N. If not, I look at the units, angle, and scale first.

A Last Check Before Using a Number

These calculations belong to fixed shapes at stated sizes and angles. They do not measure drag coefficients, the pressure on any particular patch of hide, or the footing and balance of a live animal. That is enough warning to keep beside the numbers; the fuller reasons are in Chapters 12 and 13.

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