

Begin your response to **QUESTION 2** on this page.

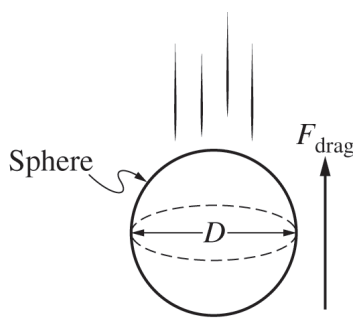


Figure 1

2. A student drops a sphere of mass m from rest. The air exerts a drag force of magnitude F_{drag} on the sphere, as shown in Figure 1. The student models the magnitude of the drag force as $F_{\text{drag}} = bv$, where v is the speed of the sphere and b is a positive constant with appropriate units.
- (a) **Derive**, but do NOT solve, a differential equation that could be used to determine the speed v of the sphere as a function of time t . Express your answer in terms of given quantities and physical constants, as appropriate.

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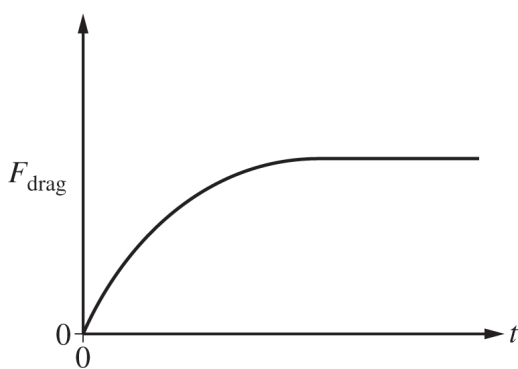


Figure 2

- (b) The student sketches the drag force F_{drag} exerted on the sphere as a function of time t , as shown in Figure 2.
- i. **Draw** a vertical line on the sketch in Figure 2 to indicate the earliest time at which F_{drag} is equal to the magnitude of the weight of the sphere, which occurs when the sphere reaches terminal speed. Label this time as t_T on the time axis.

- ii. **Justify** the location of t_T . Explicitly reference appropriate features of the sketch in Figure 2.

- (c) Suppose the student throws the same sphere downward with a nonzero initial speed. The magnitude of the new drag force at terminal speed after being thrown downward is F_{new} .

Indicate whether F_{new} would be greater than, less than, or equal to the magnitude of F_{drag} at terminal speed represented in Figure 2.

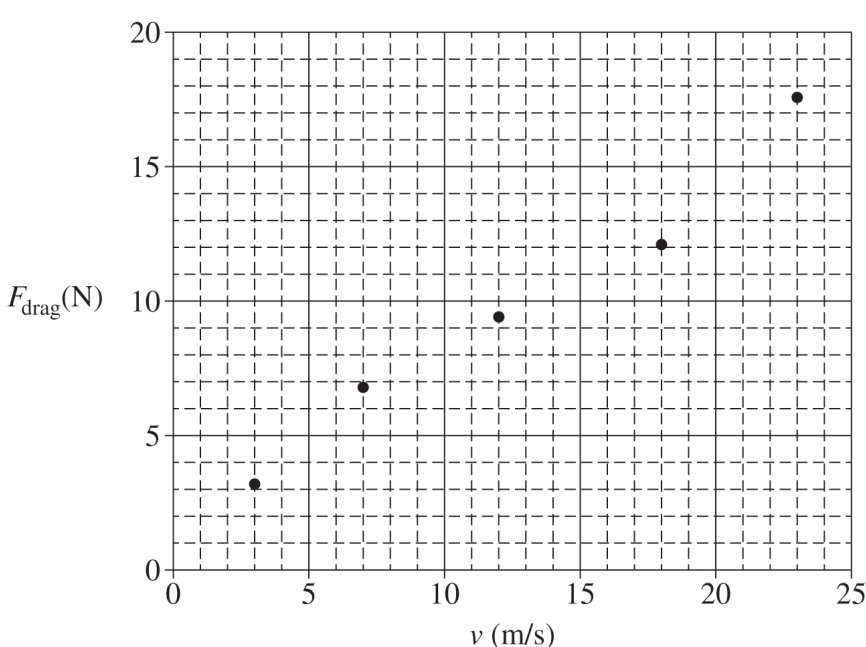
_____ Greater than _____ Less than _____ Equal to

Briefly **justify** your answer.

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- (d) The student conducts an experiment to better understand the relationship between F_{drag} and v . The student makes measurements to calculate and graph the magnitude of F_{drag} as a function of v for the falling sphere.



- i. **Draw** the best-fit line for the data.
- ii. Use the best-fit line to **calculate** an experimental value for b .

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A student claims that the terminal speed v_T of the sphere depends on the diameter D of the sphere. The student designs an experiment to collect data that can be used to provide evidence to support the claim.

- (e) The student has access to but does not have to use all of the following equipment.

- Sphere Set 1: spheres of the same known mass with different known diameters
- Sphere Set 2: spheres of the same known diameter with different known masses
- A motion detector that can measure velocity as a function of time

- i. **Indicate** two quantities that when graphed could be used to determine whether the diameter of the sphere affects the terminal speed.

Vertical axis: _____ Horizontal axis: _____

- ii. Briefly **describe** how the quantities graphed could be used to determine the relationship between sphere diameter and terminal speed.

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