(1) True or false:

$$\frac{\partial Q(\vec{r},t_1)}{\partial t} = \frac{DQ(\vec{r}_p(t_1),t_1)}{Dt} = \frac{dQ(\vec{r}_{obs}(t_1),t_1)}{dt}$$

when $\vec{r} = \vec{r}_p(t_1) = \vec{r}_{obs}(t_1)$. That is, the three derivatives above are equal when the observer (or probe) and the parcel are at the same location, $\vec{r}$, at the same (particular) time, t_1.

(A) True (B) **False** *[If the observer and parcel are both moving and are moving at different velocities, and if the field of Q varies spatially and/or over time in a way that varies spatially, then there is no reason to expect that the three derivatives would be the same (though they could be the same in special cases). This is true even though they are evaluated at the same place and time. Finite difference estimates of the three derivatives make this point especially clearly.]*

(2) True or false: The *change* or *difference* in some quantity and the *rate of change* of that quantity with respect to time have the same dimensions.

(A) True

(B) False *[If we write the change or difference in some quantity, Q, as $Q_2 - Q_1$, then it should be clear that $Q_2 - Q_1$ has the same dimensions as Q. In contrast, the rate of change of Q, which can be $\frac{\partial Q}{\partial t}$, $\frac{DQ}{Dt}$, or $\frac{dQ}{dt}$, the dimensions would be the dimensions of Q/time.]*

(3) True or false: A *change* or *difference* in some quantity and the *rate of change* of that quantity with respect to time are two different ways of saying the same thing.

- (A) True
- (B) **False** *[A <u>change</u> in a quantity and the <u>rate of change</u> of that quantity have different dimensions, so they can't be the same thing at all. Of course, the two are related: a finite difference estimate of a rate of change includes the change of the quantity in the denominator. However, the rate of change has a dimension of time in the denominator that a the change in a quantity lacks.]*

(4) <u>True or false</u>: If $Q(\vec{r}, t)$ is a field variable,

then so is $\partial Q(\vec{r}, t)/\partial t$ (the local derivative of *Q*).

(A) **True** *[A field variable is a quantity that varies continuously from place to place (that is, with position) and with time. To make this clear, we write it as $Q(\vec{r}, t)$, where the location in space where Q is evaluated ($\vec{r}$) is independent of the time when it is evaluated (t). If Q exists and varies from place to place continuously and from time to time at each place continuously, then $\partial Q(\vec{r}, t)/\partial t$ can be defined at each location at any time, so it, too, will vary from place to place and time to time and must be a field variable.]*

(B) False

(5) True or false: If $Q(\vec{r}, t)$ is a field variable, then so is

$$\nabla Q(\vec{r}, t) = (\partial Q/\partial x, \partial Q/\partial y, \partial Q/\partial z)$$
$$= (\partial Q/\partial s, \partial Q/\partial n, \partial Q/\partial z)$$

(the [vector] gradient of *Q* and its scalar components in any coordinate system, such as rectangular and natural coordinates, where $\vec{r} = (x, y, z) = (s, n, z)$ in these two coordinate systems, respectively).

(A) **True** *[The argument is basically the same as for* $\partial Q(\vec{r}, t)/\partial t$*.]*
(B) False

(6) What is true about *advection* (of a field variable)?

(A) It is a process that contributes to changes in the field variable over time observed at a fixed location.
[This is true. Advection is the process or mechanism that contributes to changes w/r/t time in some field variable, a physical property of a fluid, observed at a fixed location. In particular, a fluid parcel leaves the location and another one replaces it but with a potentially different value of some physical property.]

(B) It accounts for the transport of the field variable by a fluid to a fixed location from somewhere else.
[This is also true. When a parcel leaves some particular location, it transports it's physical properties with it, and when a new parcel arrives to replace the departing parcel, it transports it's physical properties to the new location. This is an alternative way to describe how advection works.]

(C) It has dimensions of the field variable over time.
[This is also true. It appears as a term in the equation that relates the material derivative to partial derivatives (solved for the local derivative), and so must have the same dimensions as the time derivatives.]

(D) It depends on (a) the gradient of the field variable (in the direction of the fluid flow) and (b) the speed of the fluid.
[This is also true. Advection contributes to changes in some field variable at a fixed location at a rate that depends on how fast the fluid is moving and how large the gradient of the property is in the direction of the fluid flow.]

(E) All of the above.