You have four hours to take this exam. The questions are equally weighted. Good luck!

1. In the 11-page typewritten handout on fisheries economics, Section 3 claims that with case (13), "you should find that extinction is possible, and furthermore that whether extinction occurs or not depends on whether r is less than or greater than δ." Also, it can be shown that under the assumptions of Section 3, (13d) results in

$$\dot{h}_t = \frac{[\delta - F'(x_t)][\phi(h_t) - c]}{\phi'(h_t)}$$
$$\dot{x}_t = F(x_t) - h_t\,.$$

Using these equations (which you do not have to prove), draw all qualitatively distinct phase-plane diagrams and investigate the possibility of extinction in the different cases. To what extent does r being less than or greater than δ affect the possibility of extinction? Be sure to eliminate phase-plane paths which result in negative profit for all dates.

2. (a) Show that in the presence of innovation, a firm saves more under a tradeable permit market system than under a performance standard, assuming that the price of permits is held fixed.

   (b) Now relax the assumption that the price of permits is fixed. Will the price of permits change in the presence of innovation, and if so, will it go up or down? If the price of permits changes, is it still true that "a firm saves more under a tradeable permit market system than under a performance standard"?

3. Figure 4.5 on p. 124 of Hanley, Shogren, and White's book illustrates two features of pollution taxes: (a) in order to set the correct tax, the regulator needs to know the location both of the marginal abatement cost (MAC) and of the marginal damage cost (MDC, defined on p. 123); and (b) pollution taxes result in the firm paying more than the "extended PPP" (defined on p. 124) which may be unfair. (In Figure 4.5, think of the firm starting out at the right-hand part of the graph, then moving left, abating emissions, until that becomes more expensive than paying the tax.)

   Consider a new kind of pollution tax which is *nonlinear*: this sets the tax identically equal to the MDC curve, instead of setting the tax equal to a horizontal line on Figure 4.5. Does this new, nonlinear tax scheme make problems (a) and (b) better, worse, or stay the same?

4. Beard and Lozada (p. 21–22) include the following among Georgescu-Roegen's "main epistemological conclusions":

    1. The set of real numbers is an entity built from the unions of sets of discretely distinct elements, and thus cannot correspond to the continuum of our experience.

    4. Many phenomena of economic significance, such as the development of economic institutions, cannot be understood, nor even defined, by atomistic investigations that seek to establish the properties of wholes only by reference to properties of the constituent parts. Societies, as well as species, undergo evolutionary development.

    6. Models that are constructed from ordinary functions on real numbers are termed arithmomorphic, and such models are mechanical analogies.

    7. The economic process cannot be adequately represented by mechanical analogies, because such analogies cannot represent any evolutionary process.

    Use these conclusions, or their general implication or implications, to construct a critique of neoclassical resource economics models such as the Hotelling Model. (It might help to think about how Georgescu-Roegen might criticize the Solow growth model of neoclassical macro-economics.)