1. \( W = \int_0^h F \, dz = mg \, h = 30 \, \text{kg} \times 9.8 \, \text{m/s}^2 \times 3 \, \text{m} = 234 \, \text{J} \)

\( N - m = \frac{h^2}{2} \)

2. \( W = F \cos \theta \, ds \) but \( \cos \theta = 0 \) work is only done by a component of force in the direction of travel. No work is done in this process.

3. (c) The steps don't move. In order to do work, you need both a force and some motion.

4. (c) This one is a little trickier since the diver moves. But it isn't the steps making him move. The ladder doesn't do any work — it has no source of energy. Here gravity is doing the work on the diver. Energy is transferred from the gravitational field to the diver and dispelled as heat in the diver's muscles.
5. (a) I'd like to take (b) on this one, but, also, in her correct answer. The diver
lose much work of work climbing. The
energy goes from the diver muscle
into potential energy in the gravitational
field. You can say the diver does work
on the field, or you can say the diver
does work on himself by raising himself
through the gravitational field. In either
line the energy goes into increasing
gravitational potential energy.

On the way down, the gravitational
energy goes from the field into heat
in the diver's muscles. The diver
does no work descending. Gravity does
the work.

6. (b) When potential energy is involved,
the question of what does work or
what can get very confusing. It's a
bit of a semantic maze. The
way out of the maze is to ask "where
does the energy come from?"
You could answer these questions about climbing and descending the ladder by saying that on the way up, the diner does work on himself, giving himself potential energy rather than kinetic energy. Or you could say the diner does work on the gravitational field by raising himself through it. It's a semantic distinction whether the diner possesses the potential energy in the field does.

Either way you describe it, energy is transferred from the diner's muscles to the gravitational field.

On the way down, you could say the diner does work on himself by using his weight to push himself down the ladder, dissipating his potential energy as heat in his muscles. Or you could say the gravitational field does work on the diner by pushing him the length of the ladder.

Either way, energy is transferred from the gravitational field to the diner's muscles. The diner does work going up; he is worked on coming down.
7. (1) Nobody is doing any work here because nothing is moving. (b) It is tempting but even if the rope sagged a bit, no work would be done while the diver was just standing there.

In order for work to be done, force must act to move something through a distance.

It is true that the diver must make one “effort” in order to stand on the ladder and support his weight. It is true that this effort costs energy. The reason is that muscles have internal moving parts that work when the muscle is under tension, even when not actually extending or contracting. Under static load, muscles generate heat but do no work externally.
Okay, this was harder than I meant, but it is instructive.

\[ W = F \cos \theta \, ds \]

We need \( F \). But \( F \cos \theta \) is just the frictional force \( f \). To get the friction we need the Normal force \( N \), taking into account that it is not just \( mg \), but \( mg \) reduced by the vertical component of \( F \). So, formally:

At constant speed \( (a=0) \) \( \sum F = 0 \)

Vertical: \[ N + F \sin \theta = mg \]

\[ N = mg - F \sin \theta \]

Horizontal: \[ f = F \cos \theta \]

\[ f = \mu N = \mu (mg - F \sin \theta) \]
\[ F \cos \theta = \mu (mg - F \sin \theta) \]

\[ F (\cos \theta + \mu \sin \theta) = \mu mg \]

\[ F = \frac{\mu mg}{\cos \theta + \mu \sin \theta} \]

Now we've got it.

\[ W = F \cos \theta \, \Delta s \]

\[ W = \frac{\mu mg \cos \theta \Delta s}{\cos \theta + \mu \sin \theta} \]

\[ W = \frac{\mu mg \Delta s}{1 + \mu \tan \theta} = 2.100\, J \]

So (c) is correct to one sig fig.
9. Use conservation of energy.

\[ T_i + U_i = T_f + U_f \]

\[ T_i = \frac{1}{2} m v_i^2 \]
\[ U_i = m g s \]

\[ T_f = \frac{1}{2} m v_f^2 \]
\[ U_f = 0 \]

\[ \frac{1}{2} m v_i^2 + m g s = \frac{1}{2} m v_f^2 \]

\[ v_i^2 = v_f^2 + 2 g s \]

\[ v_f = \sqrt{v_i^2 + 2 g s} \]

\[ = \sqrt{(5 \text{ m/s})^2 + 2 \times 9.8 \text{ m/s}^2 \times 4 \text{ m}} = 10 \text{ m/s} \]
10. \[ F = -kx \]

Hooke’s law says \( F = -kx \).

In this expression, \( F \) is the force exerted by the bond on the diver.

So \( F = mg \)

\[ mg = -kx \]

\[ k = \frac{mg}{-x} = \frac{50 \text{ kg} \times 9.8 \text{ m/s}^2}{20 \text{ cm}} = 2450 \text{ N/m} \]

11. (c) This is what we did in lab last week.

Whenever you recognize a spring-mass system, you get a harmonic oscillator. It oscillates about its equilibrium position.
12. (b) Once you recognize a spring-mass SHO, the motion is characterized by an amplitude $A$ and frequency $\omega$.

\[ \omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{2450 \text{ N/m}}{50 \text{ kg}}} = 7 \text{ rad/sec} \]

This "angular frequency" is the angular speed of the imaginary circular motion associated with the linear oscillation,

\[ x(t) = A \cos \omega t \]

13. (c) \[ T = \frac{2\pi}{\omega} = 0.9 \text{ sec} \]

Note also that the linear frequency is

\[ f = \frac{1}{T} = \frac{\omega}{2\pi} = 1.1 \text{ Hz} \]

Hz and rad/sec both have units sec$^{-1}$, but they differ by a factor of $2\pi$.

\[ \omega = 2\pi f \]
14. (C) Max acceleration occurs where the force is maximum.

\[ F_{\text{max}} = m \cdot a_{\text{max}} \]

Force is max at greatest displacement. Upward accel is when force is upward. Thats at max downward deflection.

15. (C) Max velocity occurs after the force has had a chance to accelerate the mass. Its at the equilibrium point.

\[ x \]

\[ v \]

\[ a \]
16. (a) 
\[ \ddot{\chi} = A \cos \omega t \]
\[ \ddot{v} = -A \omega \sin \omega t \]
\[ a = -A \omega^2 \cos \omega t = -\omega^2 \chi \]
\[ a_{\text{max}} = -\omega^2 \chi \text{, max} \]
\[ = -\omega^2 A \]
\[ = -(7 \text{ rad/s})^2 \times 10 \text{ cm} = -4.9 \text{ m/s}^2 \]

17. (b) 
\[ v_{\text{max}} = (-A \omega \sin \omega t) \text{, max} \]
\[ v_{\text{max}} = +A \omega \]
\[ = +10 \text{ cm} \times 7 \text{ rad/s} \times 1 \text{ cm} = 40.7 \text{ m/s} \]

18. (a) 
\[ \Sigma F = m a_{\text{max}} \]
\[ F_{\text{LCO}} - mg = ma_{\text{max}} \]
\[ F_{\text{LCO}} = m (g + a_{\text{max}}) \]

19. (d) 
\[ \omega = \sqrt{\frac{k}{m}} \text{, best mass (no dim), higher freq.} \]