

Please email me if you have questions about the exam.

Section A

Try to think about the purpose of the question. Most of these are asking about the relationship between force and motion (Newton's Second Law). So, if it asks about the motion, you are typically being asked to utilize the force information. Conversely, if it asks about forces, you are typically being asked to utilize the motion information.

Second, keep in mind that Newton's second law relates the net force with the acceleration (or change in velocity). It doesn't say anything about the velocity. If something is moving, it takes a non-zero net force to *start* it moving or to *stop* it from moving but the net force needs to be zero in order to *keep* it moving with the same speed and direction.

1. d (both objects are traveling at a constant speed and direction)
2. b (the acceleration is in the same direction as the velocity; it doesn't matter that the acceleration is decreasing, it is still speeding up – just less so)
3. d (at that moment, the object's velocity is zero but it will not stay at zero)
4. d (for slowing down, the acceleration is opposite the velocity)
5. e (constant speed and direction)
6. a (we typically don't accelerate at rates larger than free fall)
7. a (the only force acting is the weight and it doesn't change during the flight)
8. e
9. c (a non-zero net force would result in an acceleration)
10. d (the initial velocity does not need to be zero)
11. a (with no horizontal forces the ball will not accelerate horizontally)

12. e (the total momentum is conserved, not the velocity, and to determine the momentum we need the mass; for example, the total momentum can be zero [if block A's mass is exactly twice block B's], toward the right [if block A's mass is more than twice block B's mass] or toward the left, and which it is decides which way the blocks go after the collision)
13. a (note that the blocks have equal masses – use m to indicate that mass and solve for the final velocity of the combined blocks, of mass $2m$)

Section B

1. The average acceleration is the change in velocity divided by the elapsed time (from the definition of average acceleration). Plug in the initial time (1 s) to get the initial velocity (0.4 m/s). Plug in the final time (3 s) to get the final velocity (1.2 m/s). Take the difference (0.8 m/s) and divide by the difference in time (2 s) to get 0.4 m/s^2 .
2. (a) The student should throw the shoe away from shore. That requires that the student exerts a force directed away from shore on the shoe. Due to Newton's third law, the shoe would exert an opposite force on the student, pushing the student toward shore.
(b) From the definition of momentum, the shoe obtains a momentum of mv equal to $(1 \text{ kg})(20 \text{ m/s})$, which is 20 kg m/s away from shore. Due to conservation of momentum, the student must gain an equal amount but in the opposite direction. That means the student's mv must equal 20 kg m/s toward shore. Divide by the mass of the student (60 kg) to get the velocity of the student (0.33 m/s toward shore).
3. (a) Your force diagram should show the gravitational force pulling straight downward, and a normal force pushing away from the inclined surface (not straight up).
(b) Since we know the net force must be parallel to the surface, we only need to calculate the forces parallel to the surface. Of the forces that are acting, only the gravitational force has a component parallel to the surface (the normal force is perpendicular to the surface).

The magnitude of the gravitational force is $F_g = mg = (9.8 \text{ N/kg})(10 \text{ kg}) = 98 \text{ N}$.

The component directed down the inclined surface is 59 N. You can get this a number of ways (e.g., using the cosine of $+53^\circ$ or -53° , or the sine of 37°). You know it isn't $\cos 37^\circ$ because the cosine gives you the component in the direction of 0° and the gravitational force is not 37° from "down the surface".

In any event, since the only force acting parallel to the surface is this component of the gravitational force, the net force must also be 59 N and be directed down the surface.

- (c) From Newton's second law, the acceleration must be the net force divided by the mass. Divide 59 N by 10 kg to get an acceleration of 5.9 m/s^2 down the surface.
- (d) We can use the definition of average acceleration, since we know the acceleration and we know the change in velocity. In this case, the change in velocity is 8 m/s down the incline (since it starts with a velocity of 8 m/s up the incline and ends with a velocity of zero). Notice that the direction of the change in velocity is the same as the direction of the acceleration (which must necessarily be true).

Once the change in velocity is known, use the definition of average acceleration and solve for the time:

$$\Delta t = \frac{\Delta v}{a_{\text{avg}}}$$

It is always a good idea to check your derivation to make sure the units work out. Dividing (8 m/s) by (5.9 m/s^2) gives 1.36 s.

- (e) In order to not slide down, the net force on the box (once it stops) must be zero. Since the net force without friction is 59 N (see part b), that means the friction must completely counter that. Consequently, the friction would need to be 59 N (up the incline).
- (f) To find the coefficient, we need to use the relationship between friction and normal force $f = \mu N$. This means we first need the normal force value.

To find the normal force, apply Newton's second law to the direction perpendicular to the surface. Since the object doesn't

accelerate in that direction, the net force in that direction must be zero. Since the friction force is parallel to the surface, not perpendicular, the only two forces we need to concern ourselves with is the normal force (pointing away from the surface) and a component of the gravitational force (pointing into the surface).

Since the component of F_g parallel to the surface was obtained using the cosine of 53° (or the sine of 37°), the component perpendicular to the surface is obtained using the sine of 53° (or the cosine of 37°). This gives a value of 78.3 N into the surface. That means that the normal force must be 78.3 N out of the surface.

Now we can find the coefficient of friction by rearrange $f = \mu N$ to get $\mu = f/N$ and solving for μ :

$$\begin{aligned}\mu &= f/N \\ &= (59 \text{ N})/(78.3 \text{ N})\end{aligned}$$

which gives a value of 0.75.