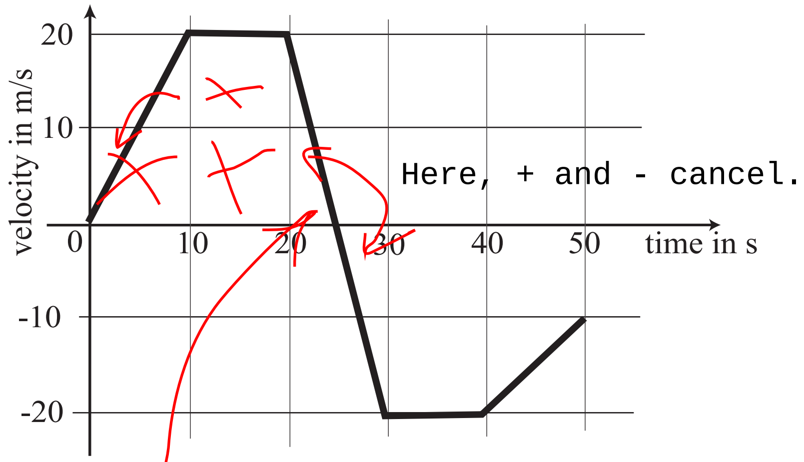
Name: ____________________ **Section:** __________ **Score:** __________ /20

1. A box of mass $M = 13$ kg is moving along the x-axis. Its velocity is approximately described in the following graph.



(a) What is the largest (in magnitude) force acting on the box before 50 s? [5]

```
This corresponds to the max slope (the steepest slope).
It is 40/10 = (-)4 m/s^2.  Therefore, the force ma = 13 x 4
= 52 N.
```

(b) What is the mean velocity of the box between $t = 0$ and $t = 30$ s? [5]

```
Mean velocity = (Displacement during T)/T.
The total displacement is the area (signed area below the graph),
which is, in this case, total 3 squares (marked with X) = 300m.
Therefore, 300/30 = 10 m/s is the mean velocity.
```

(**2** on the next page)

2. From the top of a tower of height h a ball is thrown vertically upward with an initial velocity v_0. The ball reaches its highest point after 1 s, and falls to the ground after 4 s (i.e., 3 s after reaching the highest point).

(a) What is the initial velocity v_0? [5]

```
The velocity at the top vanishes, so
     0 = v_0 - gt = v_0 - 9.8
that is,  v_0 = 9.8 m/s.
```

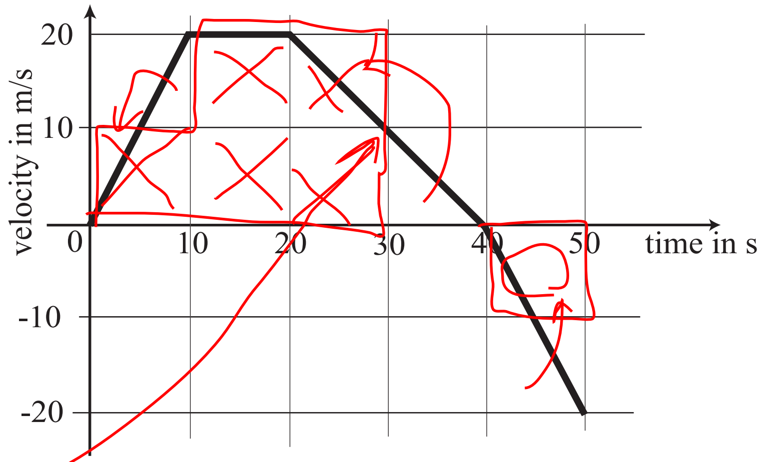
(b) What is the height h of the tower? [5]

```
Clever solution:
     1 s free fall from the highest point reaches the top of the
          tower
     3 s free fall from the highest point reaches the ground.
Thus,
     h = (1/2)g 3^2 - (1/2)g 1^2 = 4g = 39.2 m

Or
Use x = x_0 + v_0 t +(1/2)at^2 with x = 0, x_0 = h, v_0 = g, and
a = -g for t = 4.
     0 = h + 4g - 8g, so h = 4g.
```

Name: ________________ **Section:** ________ **Score:** ________/**20**

1. A box of mass $M = 7$ kg is moving along the x-axis. Its velocity is approximately described in the following graph.



(a) What is the magnitude of the force acting on the box at $t = 30$ s? [5]

Here, the slope is -20/20 = -1 m/s^2. This is the acceleration at this time. Mr. Newton tells us that the force (magnitude) is 1 x 7 = 7 N.

(b) What is the displacement of the box from $t = 0$ to $t = 50$ s? [5]

If you look at the graph, there are 5 (+)boxes (marked with X), and 1 (-)box (marked with O). Therefore, there are net 4 (+)boxes. One box = 100 m displacement, so the total displacement is 400 m.

(**2** on the next page)

2. A toy rocket is launched vertically at $t = 0$, and exhausts its fuel at $t = 2$, but keeps going up vertically. It reaches its highest point at $t = 3.5$ s. Then, it falls to the ground at $t = 6$ s.

(a) What is the velocity v_0 of the rocket just after the fuel is exhausted at $t = 2$ s? [5]

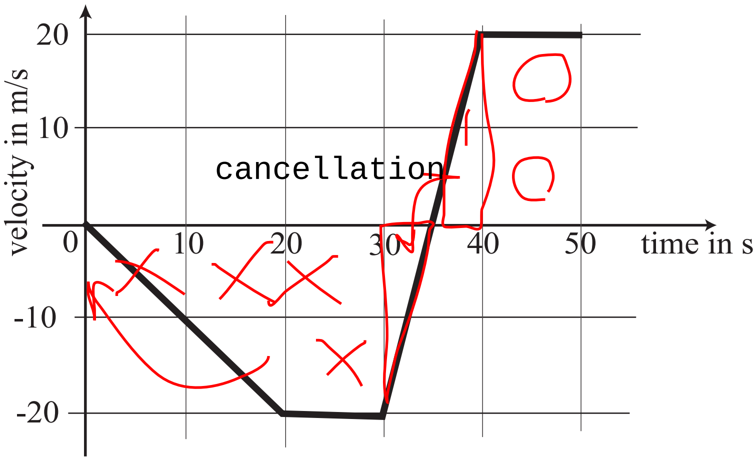
```
After exhausting the fuel, it takes the rocket 1.5 seconds to reach
the highest point: that is, the (y)-velocity vanishes after 1.5 s.
Therefore,
     v = v_0 - gt = v_0 - 9.8 x 1.5 = 0.
That is,
     v_0 = 14.7 m/s.
```

(b) What is the height H of the highest point the rocket reaches? [5]

```
It takes 6 - 3.5 = 2.5 s to fall freely (with zero
initial velocity) to the ground from the highest point:
      H = (1/2) g (2.5)^2 = 30.63 m.
```

Name: ____________ **Section:** ________ **Score:** ________/20

1. A box of mass $M = 11$ kg is moving along the x-axis. Its velocity is approximately described in the following graph.



(a) What is the maximum force acting on the box between $t = 0$ and $t = 50$ s? [5]

The max force corresponds to the max acceleration = the slope of the steepest portion. It is between 30s and 40s, so 40/10 = 4 m/s^2 is the largest acceleration the box experiences.

Therefore, Mr. Newton tells us that the max force = 4 x 11 = 44 N.

(b) At $t = 0$ the box is at the location $x = 350$ m. What is its x-coordinate at $t = 50$ s? [5]

Look at the graph above. There are 4 (-)boxes up to t = 30 s, and 2 (+)boxes beyond t = 40 s. [4.5 (-) boxes and 2.5 (+) boxes.], so there are net 2 (-)boxes. Therefore, the total displacement is -200 m. Since the initial position is +350 m, the final position must be 350 - 200 = 150 m.

(**2** on the next page)

2 From the top of a tower of height h a ball is thrown vertically upward with an initial velocity v_0. The ball reaches its highest point after 1.2 s. The speed of the ball when it reaches the ground is 29 m/s.

(a) What is the initial velocity v_0? [5]

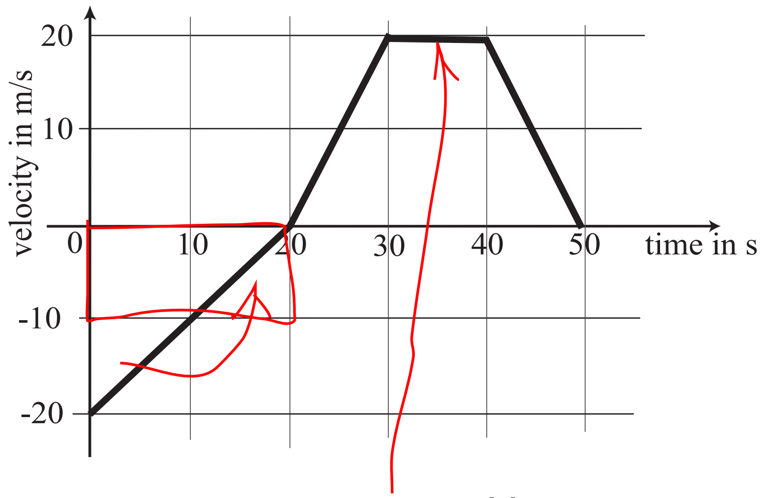
```
At the highest point the vertical velocity vanishes:
     0 = v_0 - gt = v_0 - 9.8 x 1.2.
Therefore,
     v_0 = 1.2g = 11.76 m/s.
```

(b) What is the height h of the tower? [5]

```
The net displacement of the ball from the top of the tower to
the ground is \Delta x = - h [do not forget -, because the final
point is lower.] Thus, v = 29, v_0 = 11.76, a = -g in one of the
three key formulas of 1D kinematics:
     29^2 = 11.76^2 + 2(-g)(-h).
That is,
     h = (29^2 – 11.76^2)/19.6 = 35.85 m.
```

Name: ______________ **Section:** __________ **Score:** __________/**20**

1. A box of mass $M = 19$ kg is moving along the x-axis. Its velocity is approximately described in the following graph.



(a) What is the force acting on the box at $t = 35$ s? [5]

```
The slope = 0; no change in velocity = no acceleration
= no force!  0 N.
```

(b) At $t = 0$ the box is at the location $x = 0$ m. At what time t does the box return to the origin before $t = 50$ s? [5]

```
Up to time t= 20 the displacement is -200 m (2 (-)boxes).  Between
t = 20 s and 30 s, the displacement is 100 m (one (+)box).  Therefore,
to return to the origin, we need +100 m displacement more.  Between
t = 30 s and 40 s, the displacement is 200 m, but the speed is constant,
so at t = 35 s, the extra +100 m displacement should be accomplished.
     Thus, t = 35 s is the answer.
```

(**2** on the next page)

2. A box of mass M is moving on a horizontal frictionless surface at a speed $v_0 = 7$ m/s. At $t = 0$, it goes into a rough patch of width $L = 2.5$ m, on which the acceleration in the x direction of the box is -11 m/s^2.

(a) What is the displacement of the box between $t = 0$ and $t = 1/2$ s? [5]

```
This is a 1D displacement under constant acceleration, so we can use
     x = x_0 + v_0 t + (1/2) a t^2.
Here, x_0 = 0, v_0 = 7, a = - 11 (do not forget the negative sign),
and t = 1/2:
     x = 7(1/2) − 11/8 = 2.125 m
```

(b) Can the box cross the rough patch (or does it stop inside the rough patch)? You must justify your answer. [5]

```
Let us try to calculate the final speed v, assuming that
the box reaches the other end.  If the speed there cannot be
real, the box does not reach the other end: let us use
     v^2 = v_0^2 + 2 a \Delta x
with v_0 = 7, a = - 11, and \Delta x= 2.5:
     v^2 = 49 - 55 < 0  No way.

Or, you can try to calculate where the box stops: we use the
same formula with v = 0, v_0 = 7, a = -11:
     0 = 49 - 22\Delta x,
so \Delta x = 49/22 = 2.227 m  < 2.5 m.  That is, the box
cannot get out of the rough patch.
```