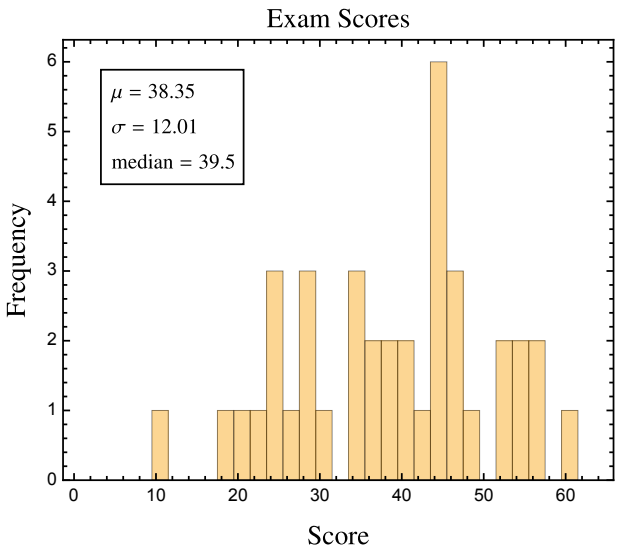
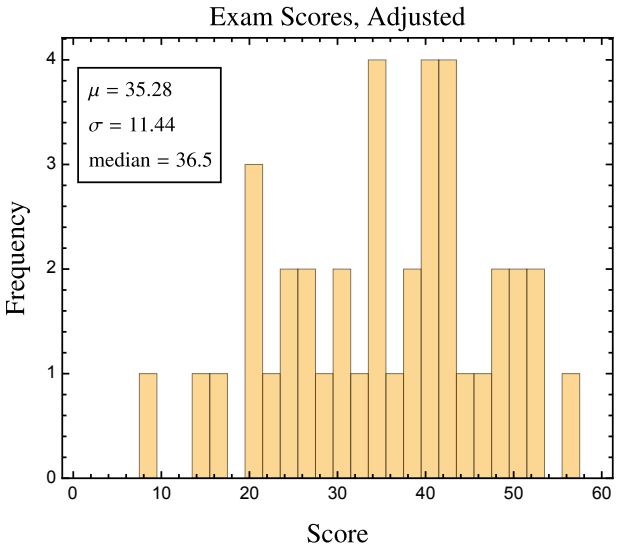
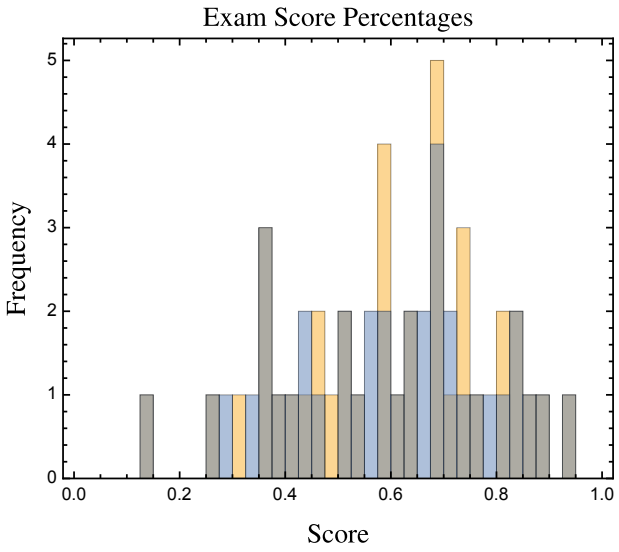
Contents



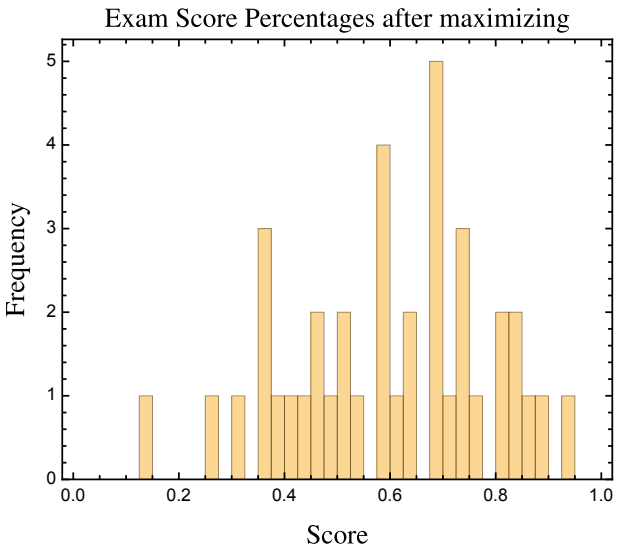
(a) The distribution of scores on Midterm 1, where problem 2 is out of 24 points, and the total possible score is 64 points



(b) The distribution of scores on Midterm 1, where problem 2's score is adjusted to be out of 20 points so that all three problems are weighted evenly. The maximum possible score is thus 60 points.



(c) The distribution of % scores on Midterm 1. The percentages of the 64-point scores are shown in orange, and the percentages of the adjusted 60-point scores are shown in blue



(d) The distribution of % scores on Midterm 1, after the maximum percentage score (out of 64 vs. out of 60) is chosen

Figure 1: Midterm 1 scores

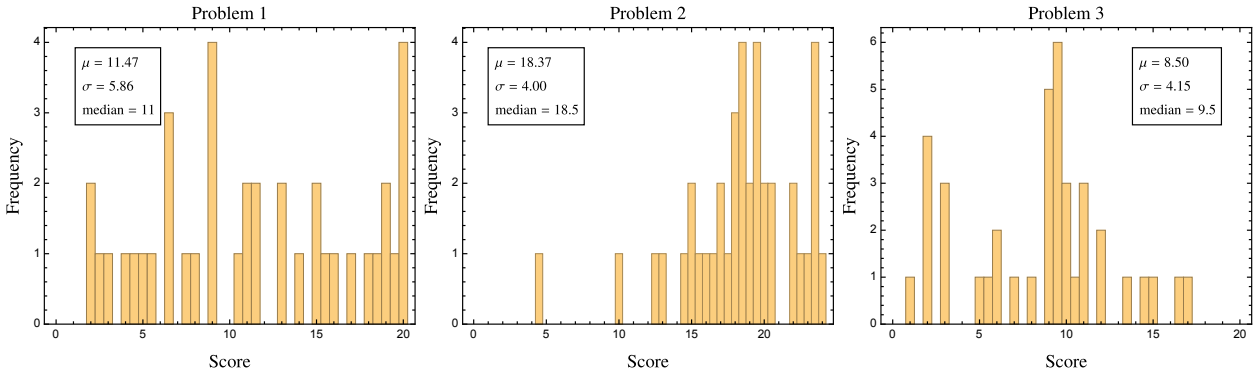


Figure 2: Breakdown of distributions by problem

0.1 Summary Histogram: Problem 1

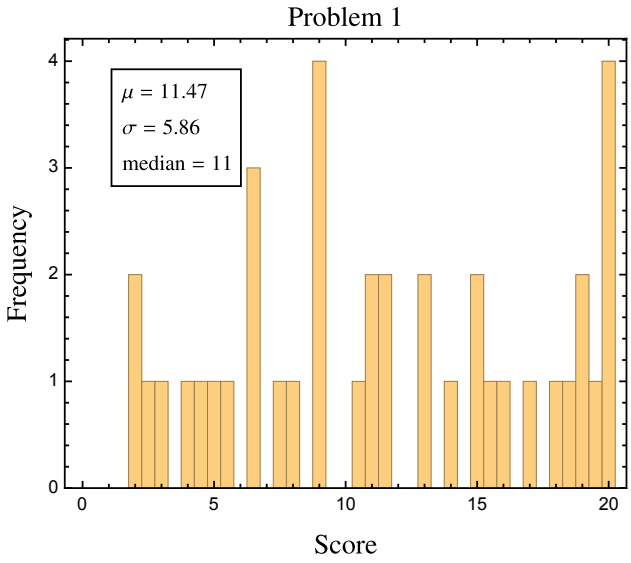


Figure 3: The distribution of scores on Problem 1

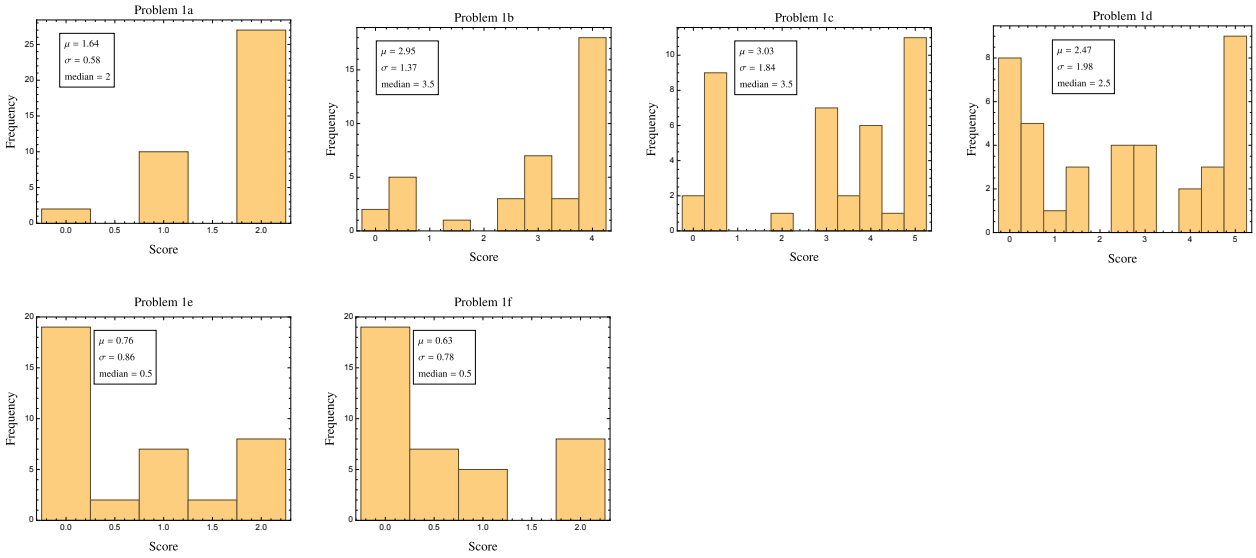


Figure 4: Breakdown of distributions by parts of Problem 1

0.2 Summary Histogram: Problem 2

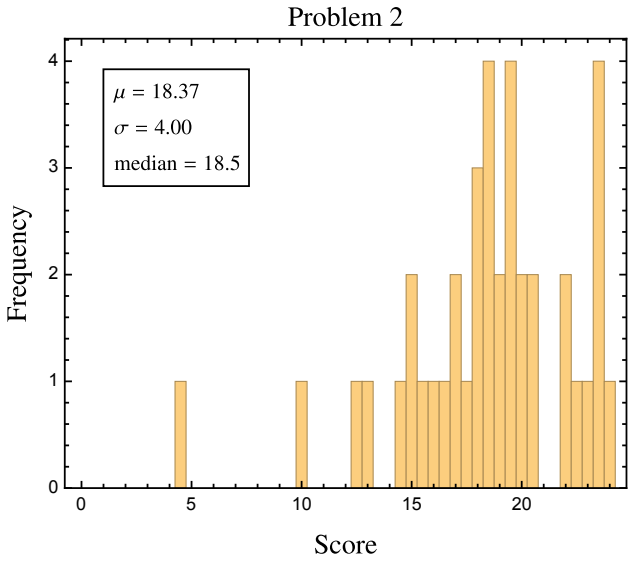


Figure 5: The distribution of scores on Problem 2

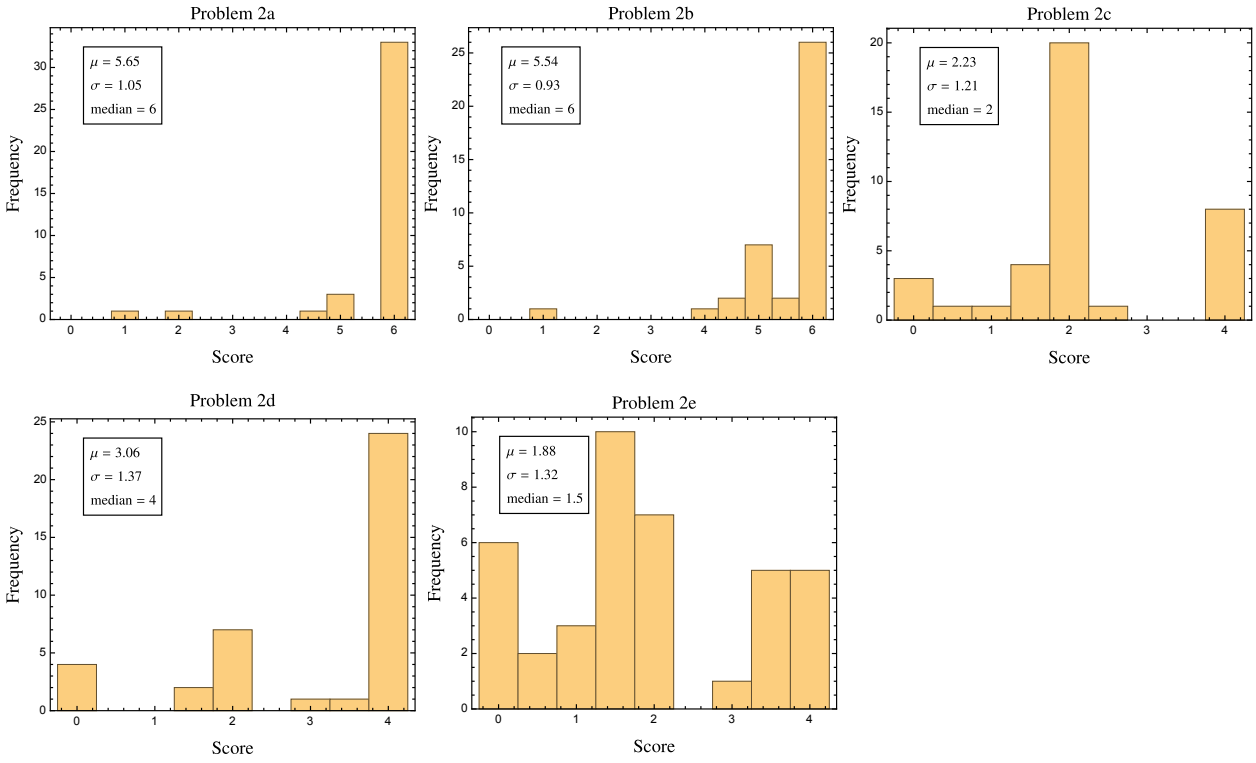


Figure 6: Breakdown of distributions by parts of Problem 2

0.3 Summary Histogram: Problem 3

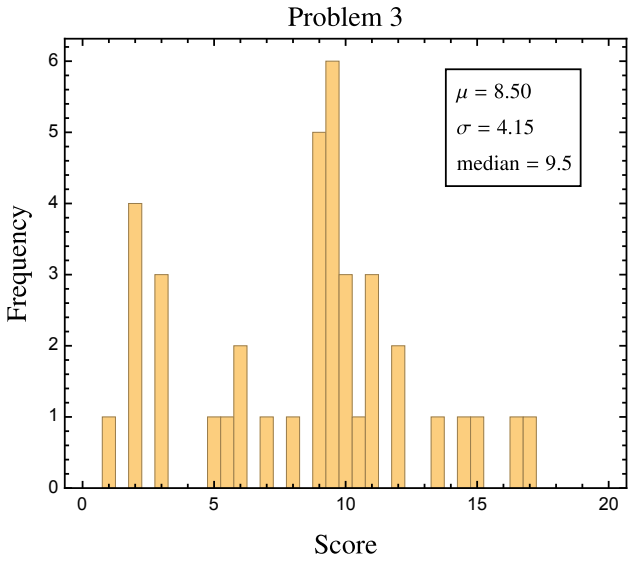


Figure 7: The distribution of scores on Problem 3

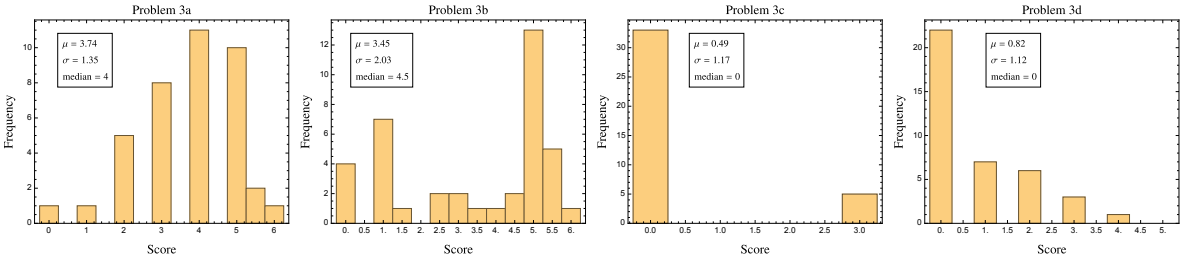


Figure 8: Breakdown of distributions by parts of Problem 3

1 Problem 1

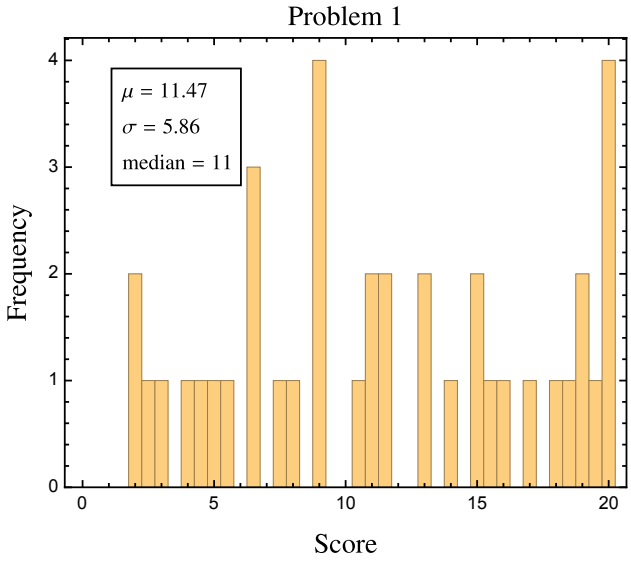


Figure 9: The distribution of scores on Problem 1

1.1 Problem 1(a) *(2 Points)*

2 points	Completely correct
1 point	Found $m(t) = -kt$ and dropped the m_0.
1 point	Made an algebra error when isolating $m(t)$.
1 point	Wrote $-gt = -v_{\text{ex}} \ln\left(\frac{m(t)}{m_0}\right)$, then solved for $m(t)$. Made the mistake of ignoring the internal forces acting on the rocket, and thought the acceleration was coming only from g.
1 point	Didn't use $\dot{m} = -k$ and instead used conservation of momentum (which isn't conserved in this problem) to find $m(t)$, deriving an exponential decay.
0 points	No answer

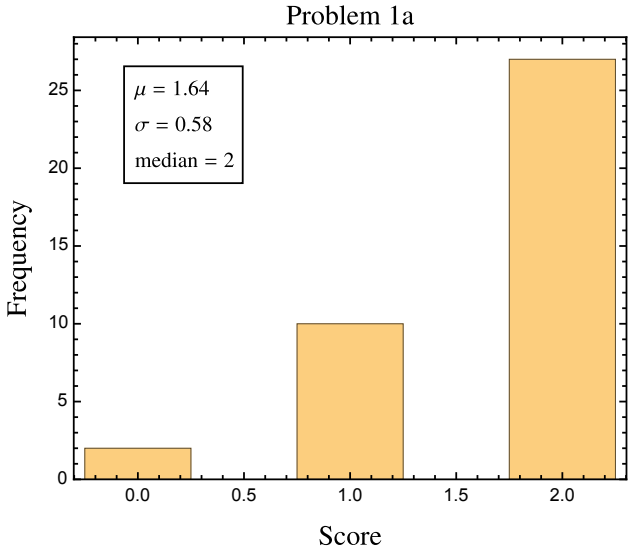


Figure 10: The distribution of scores on Problem 1a

1.2 Problem 1(b) *(4 Points)*

4 points	Completely correct
4 points	Said $dP/dt = F_{\text{ext}} = -mg$
3.5 points	Found dP but not dP/dt. Otherwise correct.
3.5 points	Everything right except that they didn't use the fact that v_{ex} was measured relative to the moving rocket, so got an extra v term in the end
3 points	Forgot to subtract of mv, so just found $P+dP$. Didn't know how to get from dP to dP/dt.
3 points	Incorrectly identified m as m_0. Otherwise correct.
3 points	Incorrectly identified m as m_0. Also made some sign errors when finding dP/dt, but otherwise conceptually correct
3 points	Conflated v and v_0, which led to setting a lot of things equal to zero and oversimplifying the differential equation. Otherwise the setup was fine.
2.5 points	Incorrectly identified m as m_0. Didn't seem to know how to go from dP to dP/dt.
2.5 points	Set up $P+dP$ right, but incorrectly assumed F_g was the only thing responsible for the acceleration of the rocket.
1.5 points	Got the setup right, but ran out of time and didn't finish from there
0.5 points	Wrote down some relevant quantities, but I couldn't follow the logic of why or where they came from
0.5 points	Said $dP/dt = 0$
0 points	Blank or completely incorrect

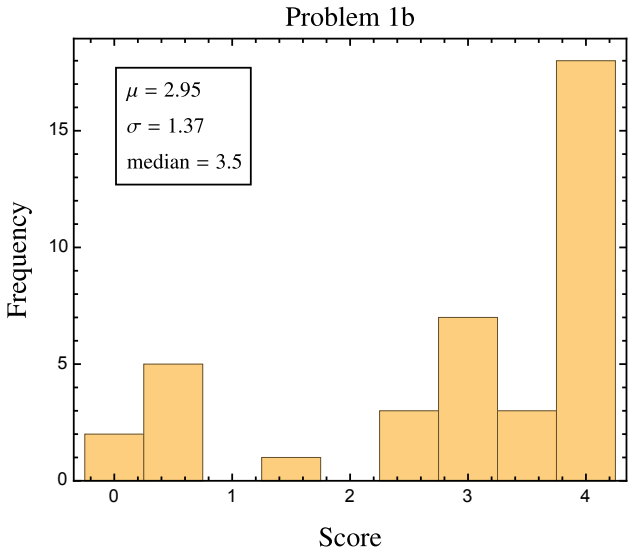


Figure 11: The distribution of scores on Problem 1b

1.3 Problem 1(c) *(5 Points)*

5 points	Completely correct
4.5 points	Completely correct except for a small sign error
4 points	Correct or consistent with previous errors, except that they left their answer in terms of m and not m_0.
4 points	Correctly got the differential equation in terms of dm/dt but didn't plug in $-k$ for that value.
3.5 points	Correctly got the equation in terms of dm/dt but didn't plug in $-k$ for that value. Also introduced at $m \to m_0$ mistake that didn't carry over from a previous part
3 points	Correct or consistent with previous errors, but mistakenly set $dP/dt = -m_0 g$ rather than $-mg$.
3 points	Correctly set $dP/dt = -mg$ but didn't know how to simplify further to eliminate dm.
2 points	Correctly set $dP/dt = -mg$ but major conceptual errors otherwise
0.5 points	Wrote down some relevant quantities, but I couldn't follow the logic of why or where they came from. Never got that $\vec{F}_{\text{ext}} = -mg$
0.5 points	Correctly established $dP/dt = -mg$ but already got credit for doing only that and nothing else in part (b)
0 points	No answer

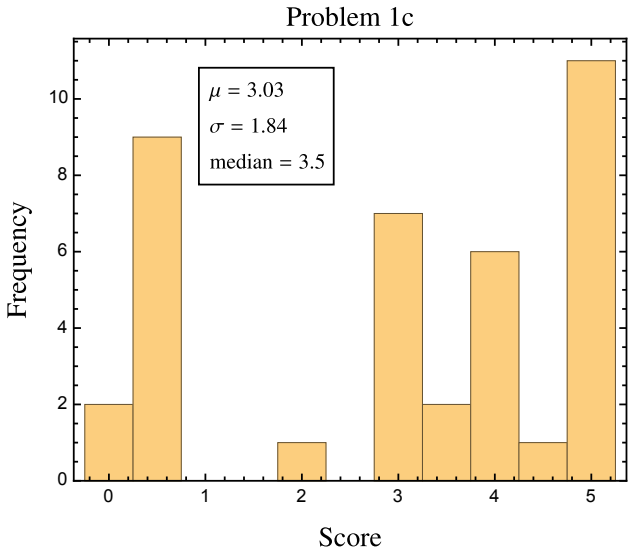


Figure 12: The distribution of scores on Problem 1c

1.4 Problem 1(d) *(5 Points)*

5 points	Completely correct or consistent with previous mistakes (that haven't veered too far off course and still require similarly complex steps to solve)
4.5 points	Correct up to a sign error
4.5 points	Correct, but left in terms of m not m_0
4 points	Correct up to forgetting the lower bound of integration
3 points	Due to previous mistakes, only had m_0 which did not depend on t, which drastically simplified the integral (no u-substitution, etc).
2.5 points	Ignored that m depended on t, which drastically simplified the integral (no u-substitution, etc).
2.5 points	Ignored that the RHS depended on t and just replaced dt with t when integrating (no u-substitution, etc).
2.5 points	Made some mistakes setting up the integral and more algebra mistakes throughout, but used u-substitution correctly. No glaring conceptual errors, but difficult to follow the algebra
1.5 points	Didn't separate variables correctly
1.5 points	Struggled to plug in $m(t)$ despite finding in correctly in part (a), never completed the integral
1 point	Major conceptual errors in which physical quantities change when being integrated over
0.5 points	Wrote down some relevant quantities
0 points	Blank

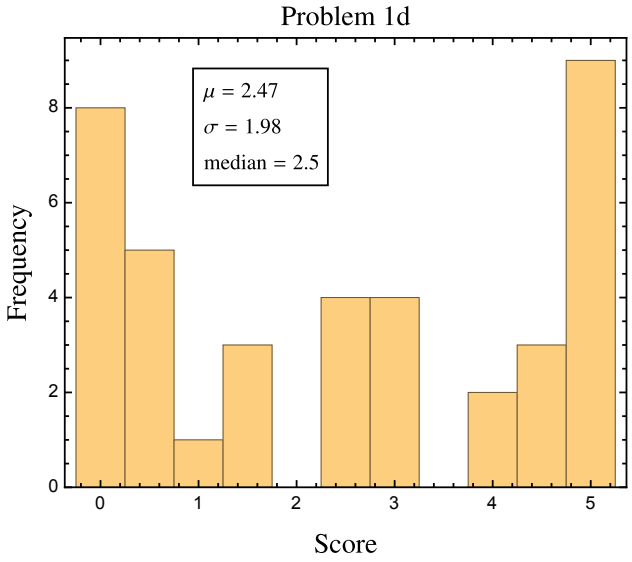


Figure 13: The distribution of scores on Problem 1d

1.5 Problem 1(e) *(2 Points)*

2 points	Completely correct
1.5 points	Correct up to a sign error
1.5 points	Correct concept, made algebra errors isolating t
1 point	Right setup, but made some conceptual errors later, not just algebra errors, when isolating t
1 points	Wrote $dv/dt = 0$ but got the wrong answer due to previous errors
1 point	Wrote $dv/dt = 0$ but assumed the only thing affecting the rocket's acceleration was g, so got the wrong answer
1 point	Wrote $dv/dt = 0$ but didn't go further or made serious errors after that
0.5 points	Wrote that $a = 0$ but didn't use $dv/dt = 0$ and couldn't simplify
0.5 points	Wrote that when a vanishes, v is constant, but otherwise it was hard to follow the logic
0 points	Wrote down something relevant
0 points	Blank

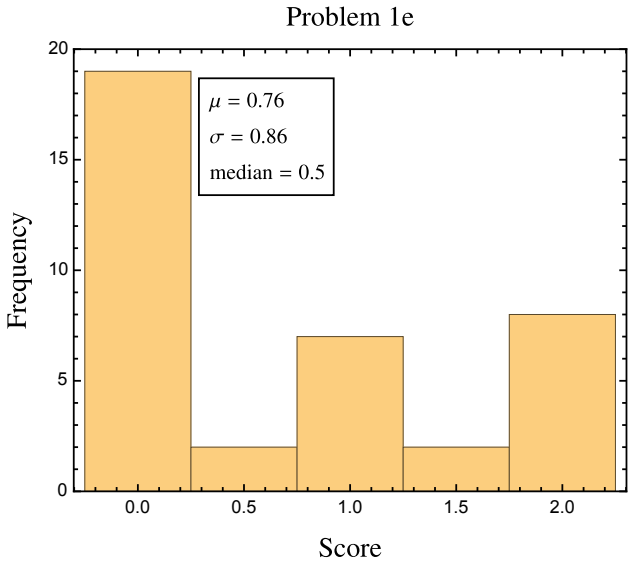


Figure 14: The distribution of scores on Problem 1e

1.6 Problem 1(f) *(2 Points)*

2 points	Correct or consistent
Pile A 2 points	Correct except wrote m instead of m_0
Pile B 1 point	Left t undetermined in the answer
Pile D 1 point	Left t undetermined in the answer, had overall wrong expression from previous parts
Pile C 0.5 points	Wrote down something relevant
0 points	Blank

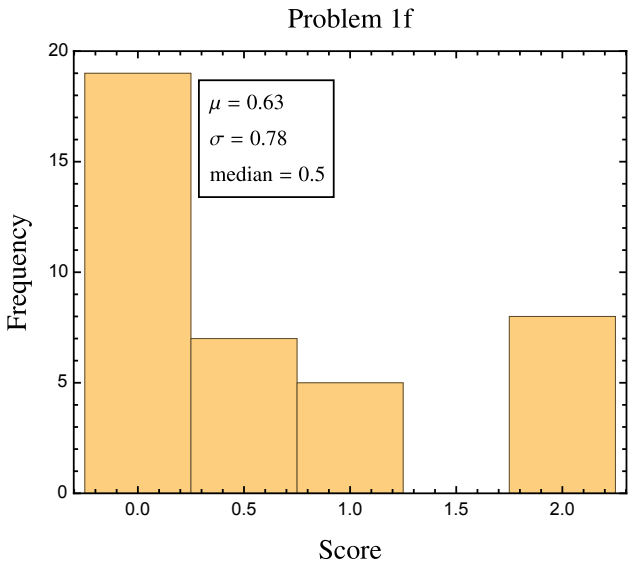


Figure 15: The distribution of scores on Problem 1f

2 Problem 2

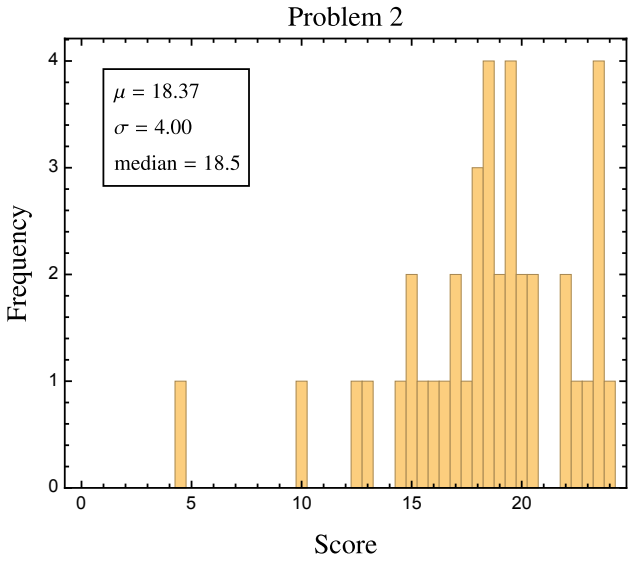


Figure 16: The distribution of scores on Problem 2

2.1 Problem 2(a) *(6 Points)*

6 points	Completely correct
5 points	Made an error setting up bounds of integration, ended up with $v = e^{-bt/m} + v_0$ instead of $v = v_0 e^{-bt/m}$
4.5 points	Set up the integral correctly, but then evaluated $\int \frac{dv}{v} = v + c$ instead of $\int \frac{dv}{v} = \ln v + c$
2 points	Said $m\dot{v} = -b$ instead of $m\dot{v} = -bv$
1 point	Knew to use $a = \dot{v}$ but didn't know how to separate variables from there
0 points	Blank

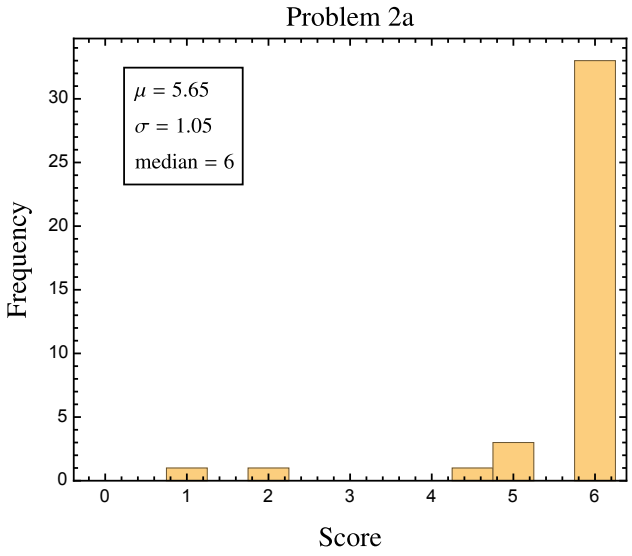


Figure 17: The distribution of scores on Problem 2a

2.2 Problem 2(b) *(6 Points)*

6 points	Completely correct or consistent
5.5 points	Correct up to a sign error
5 points	Correct up to a sign error (but that gives exponential growth...)
5 points	Incorrect bounds of integration
4.5 points	Integrated e^{at} as $1/(at)e^{at}$. Consistent otherwise
4.5 points	Consistent but earlier mistakes made the integral very easy
4 points	Consistent but earlier mistakes made the integral very easy, and there was a small mistake
1 point	Wrote something relevant
0 points	Blank

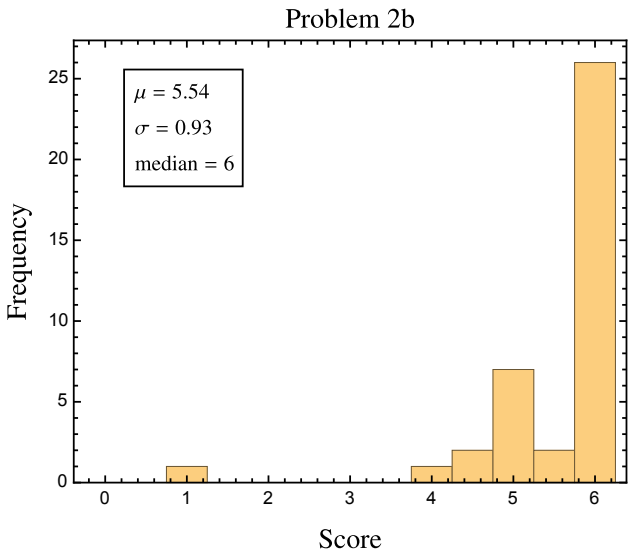


Figure 18: The distribution of scores on Problem 2b

2.3 Problem 2(c) *(4 Points)*

4 points	Completely correct or consistent
2.5 points	Set up $W = \int F_x dx$ but pulled v out of the integral and evaluated it when $x = d$.
2 points	Set up $W = \int F_x dx$ but assumed v was a constant and removed it from the integral. Or wrote $v(t)$ and still pulled it out of the integral
2 points	Set up $W = \int F_x dx$ but left v as a function of t and didn't convert it into a function of x. Went off track from there
1.5 points	Set up $W = \int F_x dx$ but assumed v was a constant and removed it from the integral. Then replaced v with v_0.
1.5 points	Set up $W = \int F_x dx$ but assumed v was a constant and removed it from the integral. Then changed their mind and wrote $W = -bd$.
1.5 points	Set up $W = \int F_x dx$, plugged in v but stopped there
1 points	Set up $W = \int F_x dx$, then changed variables from $dx \to dt$ correctly, but didn't fix the bounds of integration (so they still went from 0 to d). Then, inexplicably integrated $v_x^2 dt \to v_x^3/3$.
.5 points	Wrote down some relevant quantities but I couldn't follow the logic
0 points	Blank or not enough relevant information written down

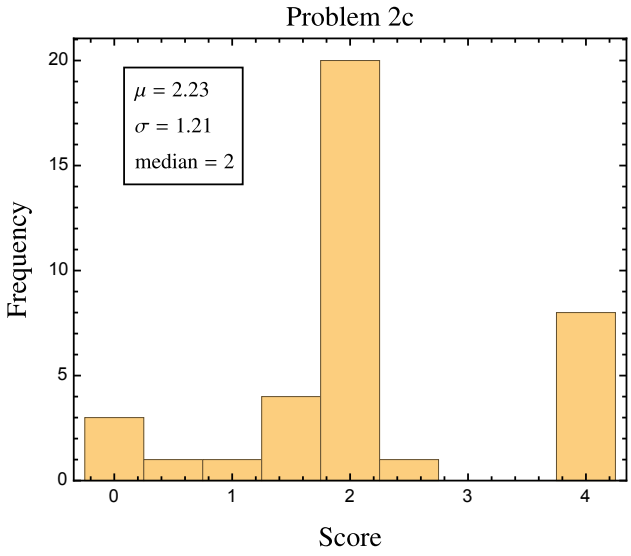


Figure 19: The distribution of scores on Problem 2c

2.4 Problem 2(d) *(4 Points)*

4 points	Completely correct
3.5 points	Thought $\Delta T = 1/2m(v_f - v_i)^2$ (really it's $\Delta T = 1/2m(v_f^2 - v_i^2)$)
3 points	Made a small algebra error, affected units of answer
2 points	Left answer in terms of t_d
0 points	Blank or not enough relevant information

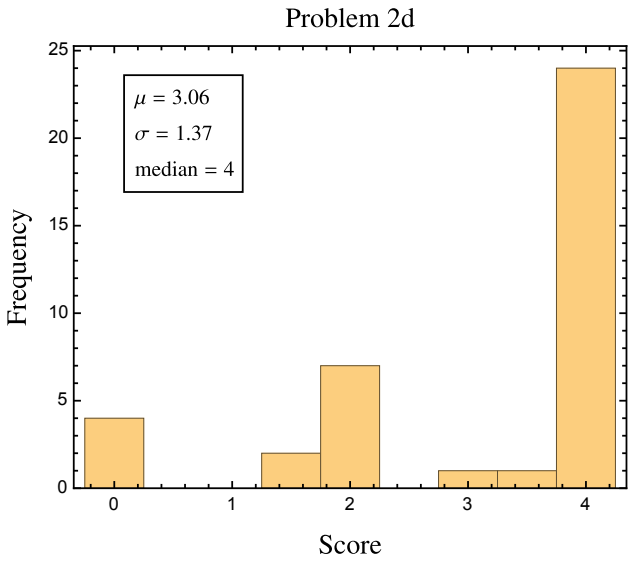


Figure 20: The distribution of scores on Problem 2d

2.5 Problem 2(e) *(4 Points)*

4 points	Completely correct
Pile C 3.5 points	Got the two of the three component corrects, made some small algebra errors for the last component
Pile A 3.5 points	Got the two of the three component corrects, ran out of time for the third component.
Pile B 3 points	Showed how to get one triple integral in one component, but made mistakes in the others. Also divided by unnecessary factors, which was difficult to follow.
Pile E 2 points	Set up the integral correctly, but didn't know how to take a volume integral
Pile H 1.5 points	Calculated the total mass, not the center of mass vector. Then got a vector in the end via a method that was unclear.
Pile F 1.5 points	Calculated the total mass, not the center of mass vector
Pile J 1 points	Calculated something like total mass, but didn't know how to take a volume integral and plugged in something strange for $\vec{r}$.
Pile G 1 points	Started with the right formula, then plugged in something for $\vec{r}$ that looked more like a moment of inertia, then didn't integrate from there
Pile I 1 points	Know how to get from dm to dV but didn't know how to plug in $\vec{r}$ nor how to take a volume integral
Pile D 0.5 points	Calculated moment of inertia, didn't make a lot of sense in this problem
0.5 points	Wrote down some relevant information
0 points	Blank or not enough relevant information

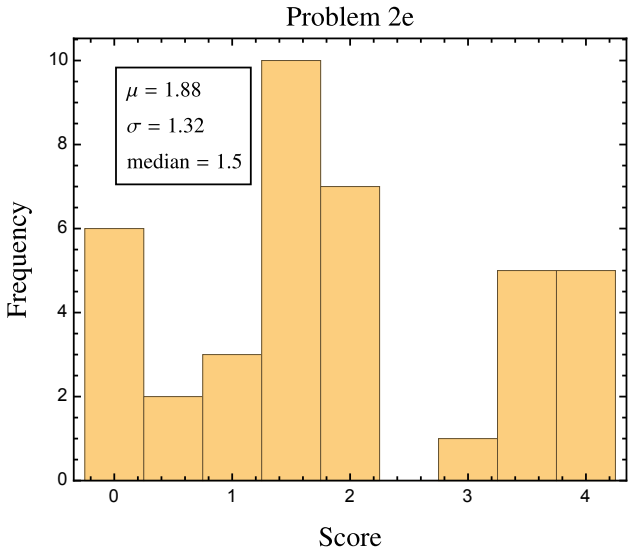


Figure 21: The distribution of scores on Problem 2e

3 Problem 3

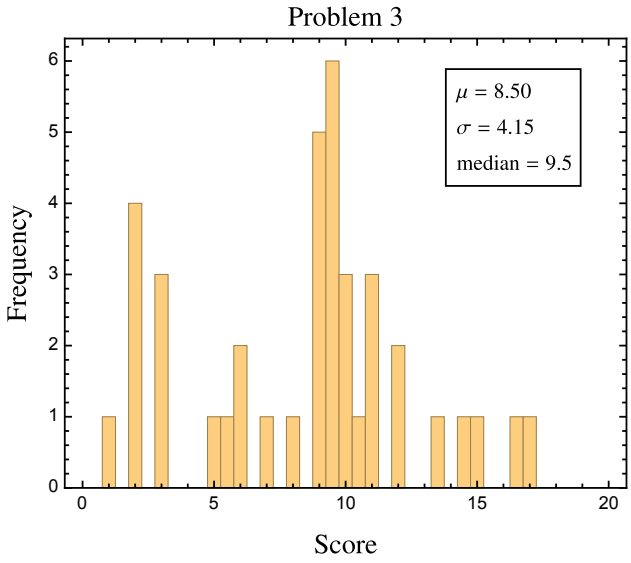


Figure 22: The distribution of scores on Problem 3

3.1 Problem 3a *(6 Points)*

- (2 pts) Wrote out the cross product in terms of cylindrical coordinates
- (1 pt) Identified the pieces of v_ρ that would vanish and simplified (you still get this point if you did this is part (b) instead)
- (1 pt) Put $m\ddot{\vec{r}}$ correctly on the RHS in cylindrical coordinates
- (1 pt)Either realized the $\ddot{\rho}$ direction was superfluous, or directly included the normal force somehow
- (1 pt) Pulled apart the vector equation into a system of equations from the components

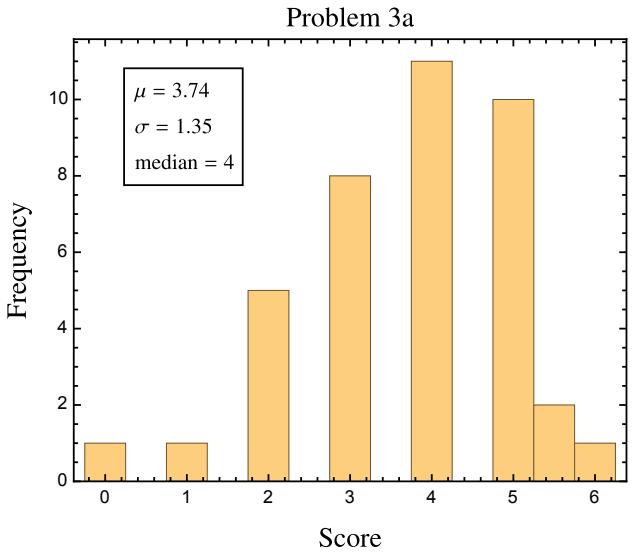


Figure 23: The distribution of scores on Problem 3a

3.2 Problem 3b *(6 Points)*

6 points	Completely correct
5.5 points	Correct up to a few dropped factors
5.5 points	Correct except for not realizing $\ddot{\rho} = 0$ or not realizing the normal force is required to set $\ddot{\rho} = 0$.
5 points	Correct except for not realizing $\ddot{\rho} = 0$, and made minor algebra errors
4 points	A lot of right things. Didn't simplify $a \to \dot{v}$. Didn't realize the normal force was required for $\ddot{\rho} = 0$.
5 points	Correct except for not realizing $v_\rho = 0$
4.5 points	Didn't realize $v_\rho = 0$ and made some minor mistakes simplifying (that left the answer in the wrong units)
5 points	Correct except for not realizing $v_\rho = 0$ and $\ddot{\rho} = 0$ (or using that the normal force is needed for $\ddot{\rho} = 0$)
4 points	Correct except for not realizing $v_\rho = 0$ and $\ddot{\rho} = 0$ (or using that the normal force is needed for $\ddot{\rho} = 0$). Also did not include the $\dot{v}_z$ equation.
3.5	Correct except for not realizing $v_\rho = 0$ and $\ddot{\rho} = 0$ (or using that the normal force is needed for $\ddot{\rho} = 0$) and made some small algebra mistakes
3 points	The expressions were correct, except at the last section $\ddot{\phi} \to \dot{\phi}$ and $\ddot{z} \to \dot{z}$.
3 points	The expressions were simplified and almost right, but $\dot{v}$ was replaced with v everywhere
2.5 points	The expressions were simplified and almost right, but $\dot{v}$ was replaced with $\ddot{v}$ everywhere
2.5 points	The expressions were simplified and partially right, but $\dot{v}$ was replaced with v everywhere and didn't realize $v_\rho = 0$
1 point	Wrote down something relevant but sometimes was too bogged down by mistakes in previous parts to simplify anything
0 points	Blank

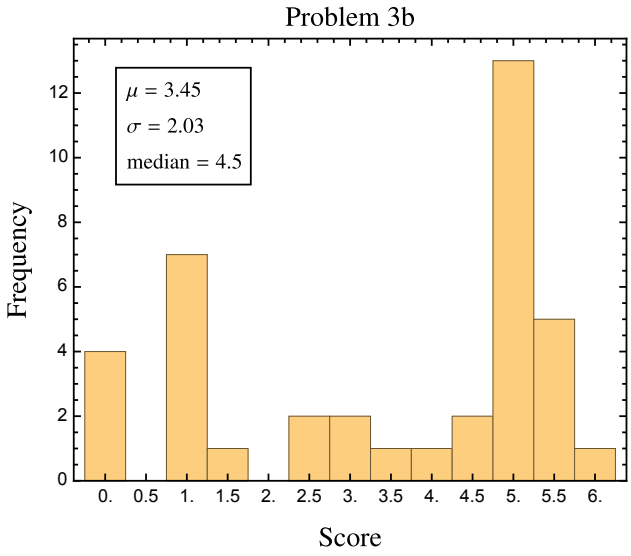


Figure 24: The distribution of scores on Problem 3b

3.3 Problem 3c *(3 Points)*

3 points	Completely correct
0 points	Wrong or Blank

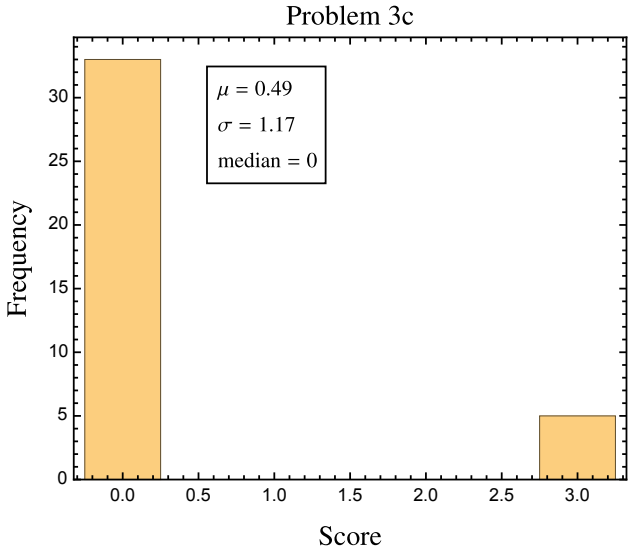


Figure 25: The distribution of scores on Problem 3c

4 Problem 3(d), 5 Points

- (1pt) Understood that in this problem, $\vec{r}\times F = \vec{\rho}\times F$
- (2 pt) Found the torque
- (1pt) Understand that if $\Gamma = 0$, angular momentum is conserved
- (1pt) Demonstrated that angular momentum is not conserved

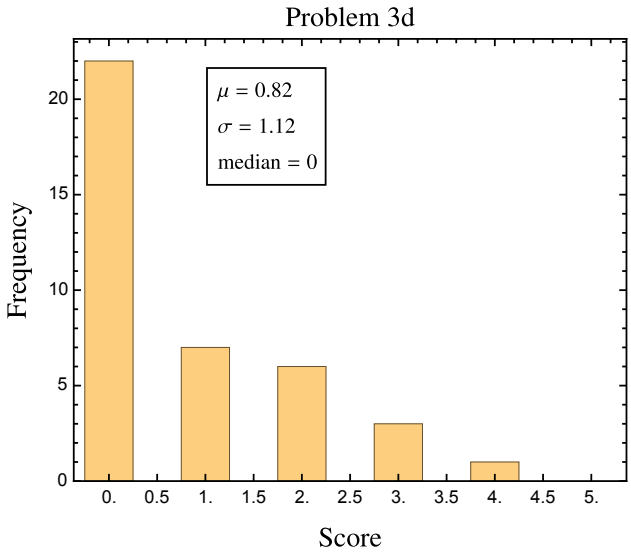


Figure 26: The distribution of scores on Problem 3d