1. [10%] True/False Questions

[1% each no partial credit]

a) T

b) F

c) T

d) T

e) T

f) T

g) F

h) F

i) F

j) T

2. [30%] Propositional Logic

2A [6%] (2% for each sentence)

1. A ⇔ ¬B
2. B ⇔ ¬C
3. C ⇔ ¬A ^ ¬B

[Partial credit: 1% if using => or <= instead of ⇔]
Accepted: A=> ¬B ^ ¬B=>A

[Alternative solution:
1. (A ^ ¬B) v (¬A ^ B)
2. (B ^ ¬C) v (¬B ^ C)
3. (C ^ (¬A ^ ¬B)) v (¬C ^ ¬(¬A ^ ¬B)]

2B. [12%]

1. A ⇔ ¬B becomes A => ¬B ^ ¬B => A Eliminate iif
   becomes **(¬A v ¬B)^ (B v A)** Replace □⇒□, with ¬□v□

   [1% per correct step + 2% for correct result] = [4%]

2. B ⇔ ¬C becomes **(¬B v ¬C)^ (C v B)** Same steps as for 1.

   [2% for correct result]

3.C ⇔ ¯A ^¯B becomes [C =>(¯A ^ ¯B)] ^ [(¯A ^ ¯B)=> C]
Eliminate iif
becomes [¯C v(¯A ^ ¯B)] ^ [¯ (¯A ^ ¯B)v C]
Replace $\alpha \Rightarrow \beta$, with $\neg\alpha \vee \beta$
becomes [¯C v (¯A ^ ¯B)] ^ [A v B v C]
De Morgan law, double negation
becomes **(¯C v¯A) ^ (¯C v¯B) ^ (A v B v C)**
Distributive law

[1% per correct step + 2% for correct result] = [6%]

[Partial credit: if starting from wrong solution in question 2A: points for the CNF steps are allocated similarly. 1% for reaching the following results
1. A => ¯B becomes ¯A v ¯B
2. B => ¯C becomes ¯B v ¯C
3. C => ¬ A^ ¬ B becomes (¬ C v ¬ A) ^ (¬ C v ¬ B)]

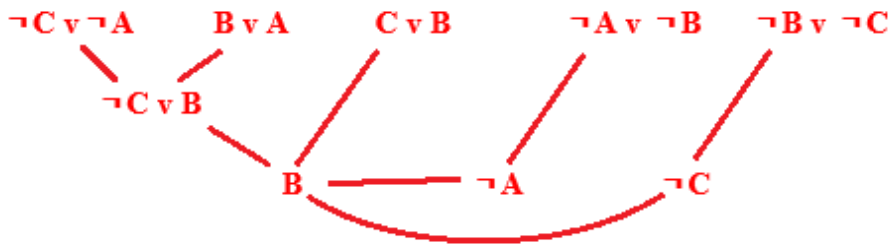
[Alternative solution:
1.[4%] [2% for distributivity + 2% for correct result]
(A v ¯A) ^ (A v B) ^ (¯B v A) ^ (¯B v B) Distributivity
(A v B) ^ (¯B v A) Remove tautologies (optional)

2. [2%] [2% correct result]
(B v ¯B) ^ (B v C) ^ (¯C v B) ^ (¯C v C) Distributivity
(B v C) ^ (¯C v B) Remove tautologies (optional)
3. [6%] [2% per step + 2% correct result]
(C ^ (¯A ^ ¯B)) v (¯C ^ (A v B)) De Morgan, double negation
(¯A v ¯C) ^ (¯B v ¯C) ^ (A v ¯B v ¯C) ^ (A v B v C) ^ (¯A v ¯C v B)
Distributivity/remove tautologies
(¯A v ¯C) ^ (¯B v ¯C) ^ (A v B v C) (Remove tautologies)
]

2C. [9%]

[2% per correct resolution step towards solution – max 8%]

Note: There may be several ways to get to the solution depending on the order of the resolution. Check that resolution involves ¯A^A, ¯B^B or ¯C^C.



Solution: Alice lies, Bob tells the truth, and Charlie lies. [1%]

2D. [1%] (No partial credit)

D⇔¯D [or anything logically equivalent]

[Alternative solution: (D ^ ¬ D) v (¬ D ^D)]

2E. [2%] (1% for both column 1&2 - 1% for column 5 – 3&4 are optional)

D	¯D	D =>¯D	¯D =>D	D <=>¯D
T	F	F	T	F
F	T	T	F	F

3. [10%] First-Order Logic : logic sentences

[No partial credit]
[Any logically equivalent solution is valid, notably A=>B can be written as ¯A v B]

3A. [2%] ∃x, Late(Lover(x)) ^ ¬ Happy(x)

[Late and Happy and be swapped for full credit]

3B. [2%] ∀x, ∀y, Waits(x,Lover(x)) => ¯Complains(x, y)

[The ∀y can be right after => for full credit]

3C. [2%] ∀x, x=Lover(Lover(x)) => Happy(x)

[Can write == instead of =]

3D. [2%] ∀x, ∀y, Waits(x,y) ^Late(y) => Complains(x,y)

[Late and Waits can be swapped for full credit]

3E. [2%] ∃x, ∀y, ¯Happy(y) v Late(y) => Complains(x,y)

[Late and Happy and be swapped]

4. [20%] Inference

[2% for each, alternative solutions, if reasonable, could also get credit]
[In each case, mention which inference rule is used [1%], and to which sentence(s) above it was applied [1%]]

(9) And-elimination on 8
(10) Modus Ponens 9, 3
(11) And-elimination on 8
(12) Modus Tollens on 5 and 11
(13) And-introduction on 8, 10, and 12 and And-elimination on 8 **[.5% * 4]**
(14) Modus Ponens on 2 and 13
(15) Either solution is correct: (i) And-elimination on 8 (ii) Modus Tollens on 4 & 12
(16) Modus Tollens on 7 and 15
(17) And-elimination on 8
(18) Modus Tollens on 6 and 14

[If only one sentence is specified in modus tollens/ponens: -0.5%]

5. [20%] Classical Planning

5A. [8%]

[-0.5% for each wrong literal]
Action: noAstronaut(S, X, Y)

[2%] Precondition:

at(S, X) [1%]

travelable(S, X, Y) [1%]

[2%] Effect:

Add: at(S, Y) [1%]

Delete: at(S, X) [1%]

Action: withAstronaut (S, A, X, Y)

[2%] Precondition:
at(S, X) [.5%]
at(A, X) [.5%]
travelable(S, X, Y) [1%]

[2%] Effect:
Add: at(S, Y), at(A, Y) [.5% each]
Delete: at(A, X), at(S, X) [.5% each]

5B. [7%]

[-0.5% for each wrong literal that is contradictory to the correct solution]
(If a student should happen to write down all the false statements (e.g., ~at(A, ES), etc.) as well, we still give full marks. However, if the false statements are incomplete, 1% will be deducted for not understanding the closed world assumption)

Initial condition:

[1%] at(B, ES),

[1%] at(C, MS),

[1%] at(A, MS),

[.5%] travelable(B, ES, EO),

[.5%] travelable(B, EO, ES),

[.5%] travelable(B, EO, MO),

[.5%] travelable(B, MO, EO),

[.5%] travelable(C, MS, MO),

[.5%] travelable(C, MO, MS),

Goal: [1%] at(A, ES)

[For the goal, besides at(A, ES) as in the correct answer, at(B, ES) can be accepted as an *additional* literal with no harm (because the problem did say that the spacecraft returns to the Earth Suface) while at(C, MO) is not necessary. So -0.5% for at(C, MO)]

[If the negative points are more than positive points, the score becomes 0]

**********BEGIN OF NOTE**********

(i) In the example in https://en.wikipedia.org/wiki/STRIPS, the Initial state is defined as:

```
Initial state: At(A), Level(low), BoxAt(C), BananasAt(B)
```

where ~At(B), etc. are not given explicitly;

(ii) Similarly, http://www-users.cs.umn.edu/~gini/4511/strips.html (the brief outline of the assumptions used when writing operators using the STRIPS language) gives the following definition for STRIPS:

Initial State:	1. conjunction of function free ground literals. The literals could be negated, but the closed world assumption is used, *so whatever is not explicitly stated is assumed to be false*.
Goal:	1. conjunction of positive ground literals
Preconditions of operators:	1. conjunction of positive literals. 2. existentially quantified variables are allowed
Effects of operators:	1. conjunction of positive and negative literals. The interpretation is that positive literals describe what is added to the world as an effect of the action and negative literals describe what is deleted from the world.

We avoid giving the knowledge like at(x) & at(y) => x=y by highlighting the closed world assumption above.

**********END OF NOTE **********

5C. [5%]

(1) noAstronaut(B, ES, EO)

(2) noAstronaut(B, EO, MO)

(3) withAstronaut(C, A, MS, MO)

(4) withAstronaut(B, A, MO, EO)

(5) withAstronaut(B, A, EO, ES)

(Note: the topological order should be 12345 or 13245 or 31245.)

[If the solution is described in plain words instead of the actions, -2% because it's more like a result of human-planning instead of the STRIPS planner]

[Deduct a maximum of 0.5% if one or more A are missing from the withAstronaut operations]

[Each correct operation: .5%]

[If the order is right, give full credit (5%)]

[Each invalid operation: -0.5%]

[Each redundant operation: -0.5%]

[If only the order is wrong (which is unlikely), give 2.5% for 5C]

6. [10%] Multiple-Choice Questions

1. [2%] c
2. [2%] b
3. [2%] c
4. [2%] d
5. [2%] b