Exam Key

Short Answer

SA1

1. In the atmosphere convection is an efficient way to move heat energy. Does the same apply to soils? Why or why not?

- No - convection is limited to fluids (liquid/gas). Conduction is the primary mode of heat transport in solids (soil). Convection relies on bulk transport of heat which (generally) does occur in soils. Conduction relies on kinetic energy transfer between individual molecules which is much more efficient in solids than fluids.

2. In soils, conduction is an efficient way to move heat energy. Does the same apply to the atmosphere? Why or why not?

No - conduction is most efficient in solids. Convection is the primary mode of heat transport in the atmosphere. Convection relies on bulk transport of heat which (generally) does occur in soils. Conduction relies on kinetic energy transfer between individual molecules which is much more efficient in solids than fluids.

SA2

1. The table below shows measurements of incoming and outgoing short-wave radiation above a fir forest on a sunny late-winter day in coastal British Columbia. Given the time of day and season, do you think these values are reasonable?

Time	SW In	SW Out	Albedo
10:00	200	150	0.75
11:00	250	300	1.20
12:00	300	360	1.20
13:00	250	275	1.10

Time	SW In	SW Out	Albedo
14:00	200	150	0.75

- No – SW out should never exceed SW in – something is wrong with obs 11:00-13:00. Possibly snow covering the sensor as covered in Lab2. **Must** mention specific timestamps that are the issue for full credit.

2. The table below shows measurements of incoming and outgoing short-wave radiation above a fir forest on a sunny late-winter day in coastal Nova Scotia. Given the time of day and season, do you think these values are reasonable?

Time	SW In	SW Out	Albedo
10:00	200	150	0.75
11:00	250	300	0.75
12:00	300	360	1.20
13:00	250	275	1.20
14:00	200	150	1.10

- No – SW out should never exceed SW in – something is wrong with obs 12:00-14:00. Possibly snow covering the sensor as covered in Lab2. **Must** mention specific timestamps that are the issue for full credit.

SA3

1. Assuming radiative inputs and soil temperatures do not change drastically, how would you expect soil heat flux density in a peatland the day after a heavy rainfall event to compare to soil heat flux density the day before a heavy rainfall event?

- Soil heat flux would increase if all else remained equal because thermal conductivity increases as a function of soil volumetric water content. For peat soils this increase is substantial because of the significant pore space in the soil.

2. Assuming radiative inputs and soil temperatures do not change drastically, how would you expect soil heat flux density in an agricultural field with mineral soils the day after a heavy rainfall event to compare to soil heat flux density the day before a heavy rainfall event?

- Soil heat flux would increase if all else remained equal because thermal conductivity increases as a function of soil volumetric water content. For mineral soils this increase is moderate because of the limited pore space in the soil.

Calculations

C1

```
Buck_Equation <- function(T){
    # Takes T in deg C and returns P_v in kPa
    P_v <- 0.61121*exp((18.678-T/234.5)*(T/(257.14+T)))
    return(P_v)
}

Ideal_Gas_Law_Vapor_Density <- function(T,P_v){
    # Takes T in deg C and vapor pressure in kPa; converts T to K; then returns the rho_v
    R <- 8.31446261815324e-3 # Ideal Gas Constant in kPa m$^3$ K$^{-1}$ mol$^{-1}$
    M <- 18.01528 # Molar mass of H20 in g m-3
    T_k <- T + 273.15
    rho_v = P_v*M/(R*T_k)
    return (rho_v)
}

# Vector of air temperature in 1 deg C intervals over over the range -10 to 40 C
T <- c(-10:40)
P_v <- Buck_Equation(T)
rho_v <- Ideal_Gas_Law_Vapor_Density(T,P_v)

# A "data frame" is a like a table
Saturation_by_Temperature <- data.frame(T,rho_v,P_v)
```

```
[1] 0.3541667
```

```
[1] 0.3541667
```

C2

```
[1] 0.3554201
```

```
[1] 2.599761
```

```
[1] 0.4672212
```

```
[1] 3.397489
```

C3 / C4

```
# The adiabatic process equation (APE)

setClass(Class="Parcel",representation(T="numeric",Td="numeric",z="numeric",LCL="numeric"))
APE <- function(Parcel,z2){
  DALR = -0.01
  SALR = -0.006
  # Calculate the LCL
  LCL = (Parcel@Td-Parcel@T)/DALR+Parcel@z
  Parcel@LCL = LCL
  # Evaluate the APE and update the parcel temperature
  Parcel@T = Parcel@T + min((LCL-Parcel@z),(z2-Parcel@z))*DALR + max(z2-LCL,0)*SALR
  # Update the parcel's height and dewpoint if necessary
  Parcel@z=z2

  if(Parcel@z>=LCL){
    Parcel@Td = Parcel@T
    Parcel@LCL = Parcel@z}
  return(Parcel)
}

#C3
#1
A = new("Parcel",T=11.0,Td=7.5,z=0,LCL=NaN)
A = APE(A,A@z)
B = APE(A,1000)
C = APE(B,0)
C
```

```
An object of class "Parcel"
Slot "T":
[1] 13.6

Slot "Td":
[1] 3.6

Slot "z":
[1] 0

Slot "LCL":
[1] 1000
```

```r
#2
A = new("Parcel",T=15.6,Td=7.5,z=0,LCL=NaN)
A = APE(A,A@z)
B = APE(A,1000)
C = APE(B,0)
C
```

```
An object of class "Parcel"
Slot "T":
[1] 16.36

Slot "Td":
[1] 6.36

Slot "z":
[1] 0

Slot "LCL":
[1] 1000
```

```r
#C4
#1
A = new("Parcel",T=17,Td=5.5,z=28,LCL=NaN)
A = APE(A,A@z)
B = APE(A,1000)
C = APE(B,0)
C
```

```
An object of class "Parcel"
Slot "T":
[1] 17.28

Slot "Td":
[1] 5.5

Slot "z":
[1] 0

Slot "LCL":
[1] 1178
```

```
#2
A = new("Parcel",T=16,Td=5.5,z=28,LCL=NaN)
A = APE(A,A@z)
B = APE(A,1000)
C = APE(B,0)
C
```

```
An object of class "Parcel"
Slot "T":
[1] 16.28

Slot "Td":
[1] 5.5

Slot "z":
[1] 0

Slot "LCL":
[1] 1078
```

C5

```
Evap <- function(T,H_L,Hours){
  rho_H2O = 1000 #kg/m3
  # Data from Figure 4 in Lab 5
  df <- read.csv(file = '../_Data/LatentHeatVaporization.csv',sep=',')
  L_v = df$Heat.of.vaporization.kJ.kg.1[df$Temperature.C==T]
  # Convert from kJ to J
  L_v = L_v*1e3 # J/kg
  E = H_L/(L_v*rho_H2O)*(1e3*3600*Hours)
  sprintf('Total evaporation %0.2f mm, given Lv at %0.2f: %0.2f',sum(E),T,L_v) # kJ/kg
}
#1
Evap(20,c(400,300,200),c(1,1,1))
```

```
[1] "Total evaporation 1.32 mm, given Lv at 20.00: 2453500.00"
```

```
#2
Evap(10,c(450,350,250),c(1,1,1))
```

```
[1] "Total evaporation 1.53 mm, given Lv at 10.00: 2477200.00"
```