CE 5364 Groundwater Transport Phenomena
Exercise Set 1

Exercises

1. A sand column has the following characteristics[1]:

$$K = 10^{-4}\frac{cm}{s};\;\; A = 75cm^2; \qquad \frac{dh}{dl} = 0.01;\;\; n = 0.20 \tag{1}$$

   Determine:

   (a) Sketch the system.

   (b) The specific discharge.

   (c) The pore velocity.

   (d) The volumetric flow rate through the column.

[1] Problem 2-3, pg. 578 in Bedient, et. al.

Sketch the system.

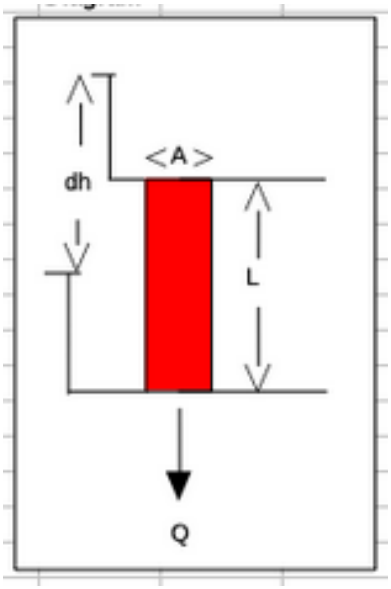

Figure 1: Sketch of Sand Column

Specific discharge

[61]:
```
K = 1.0e-04
A = 75
dhdl= 0.01
n = 0.20
```

[62]:
```
q=K*dhdl
print("specific discharge = ",round(q,6)," cm/sec")
```

```
specific discharge =  1e-06  cm/sec
```

Figure 2: Specific discharge calculations

Pore velocity

```
[63]: u=q/n
      print("pore velocity = ",round(u,6)," cm/sec")

      pore velocity =  5e-06  cm/sec
```

Figure 3: Specific discharge calculations

Volumetric flow rate through the column

```
[60]: Q=q*A
      print("Volumetric discharge = ",round(Q,6)," ml/sec")

      Volumetric discharge =  7.5e-05  ml/sec
```

Figure 4: Volumetric discharge calculations

2. Three geologic formations overlie one another with the characteristics listed below.[2]

$$\begin{aligned} b_1 &= 50\ ft & K_1 &= 0.0002\frac{ft}{s} \\ b_2 &= 20\ ft & K_2 &= 0.000005\frac{ft}{s} \\ b_3 &= 210\ ft & K_3 &= 0.001\frac{ft}{s} \end{aligned} \tag{2}$$

A constant velocity vertical flow field exists across the three formations. The hydraulic head at the top of the formations (top of formation 1) is 33 feet. The hydraulic head at the bottom of the formations (bottom of formation 3) is 21 feet.

Determine:

(a) Sketch the system.

(b) The hydraulic head at the internal boundary between formation 1 and 2.

(c) The hydraulic head at the internal boundary between formation 2 and 3.

(d) Approximate time for a tracer to flow (vertically) through the three layers if the porosities n_1, n_2, and n_3 are 0.30,0.42, and 0.35, respectively

[2]Problem 2-12, pg. 579 in Bedient, et. al.

Sketch the system.

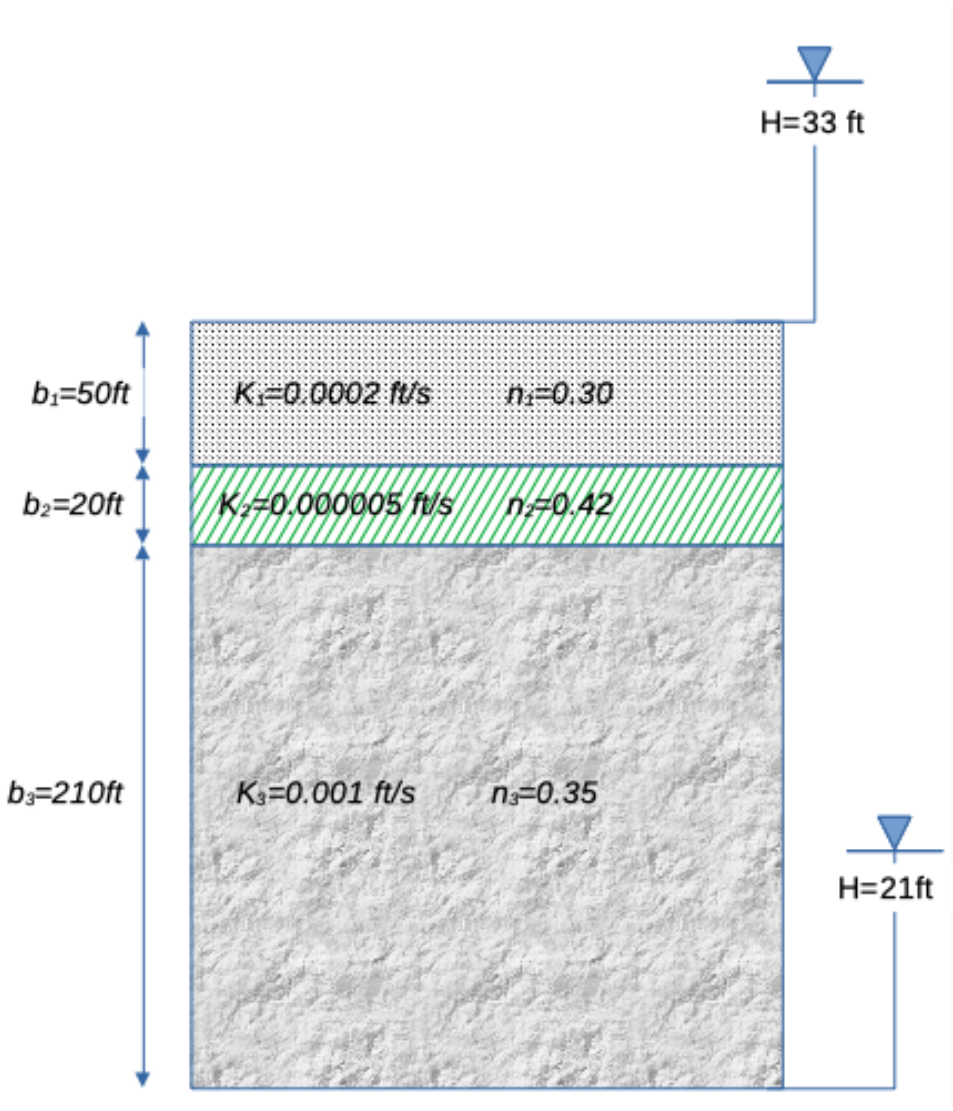

Figure 5: Sketch of Layered System

The hydraulic head at the internal boundary between formation 1 and 2.

[50]:
```
# Find total discharge per unit area through entire formation
htop=33
hbot=21
k1=0.0002
k2=0.000005
k3=0.001
l1=50
l2=20
l3=210
n1=0.30
n2=0.42
n3=0.35
Kbar=(l1+l2+l3)/((l1/k1) + (l2/k2) + (l3/k3))
print("vertical composite Kv: ",round(Kbar,6)," ft/sec")
dH=htop - hbot
dl = l1+l2+l3
qt=Kbar*dH/dl
print("vertical hydraulic gradient :",round(dH/dl,6)," ft/ft")
print("vertical specific discharge q: ",round(qt,6)," ft/sec")
```

```
vertical composite Kv:  6.3e-05  ft/sec
vertical hydraulic gradient : 0.042857  ft/ft
vertical specific discharge q:  3e-06  ft/sec
```

[51]:
```
# find head loss in layer 1
dh1 = l1*qt/k1
h12 = htop -dh1
print("head at layer 1-2 interface :",round(h12,2)," ft ")
```

```
head at layer 1-2 interface : 32.33  ft
```

Figure 6: Head at layer 1-2 interface

The hydraulic head at the internal boundary between formation 2 and 3.

```
head at layer 1-2 interface : 32.33  ft
```

[52]:
```
# find head loss in layer 2
dh2 = l2*qt/k2
h23 = htop - dh1 -dh2
print("head at layer 2-3 interface :",round(h23,2)," ft ")
```

```
head at layer 2-3 interface : 21.57  ft
```

Figure 7: Head at layer 2-3 interface

Approximate time for a tracer to flow (vertically) through the three layers if the porosities n_1, n_2, and n_3 are 0.30,0.42, and 0.35, respectively

```
head at layer 2-3 interface : 21.57  ft
```

[53]:
```
# time in layer 1
time1 = l1*n1/qt
print("tracer time in layer 1 :",round(time1,6)," sec")
```

```
tracer time in layer 1 : 5575000.0  sec
```

[54]:
```
# time in layer 2
time2 = l2*n2/qt
print("tracer time in layer 2 :",round(time2,6)," sec")
```

```
tracer time in layer 2 : 3122000.0  sec
```

[55]:
```
# time in layer 3
time3 = l3*n3/qt
print("tracer time in layer 3 :",round(time3,6)," sec")
```

```
tracer time in layer 3 : 27317500.0  sec
```

[56]:
```
totaltime=time1+time2+time3
totaltime=totaltime/86400
print("Tracer travel time :",round(totaltime,3)," days ")
```

```
Tracer travel time : 416.834  days
```

Figure 8: Travel times in layered system