aae532hw02p1

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1 AAE 532 - Problem Set 02

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1.2 10 September 2021

1.3 Packages Used:

[ ]:
```
import math as ma
import numpy as np
```

2 Part a)

2.1 Symbols:

2.1.1 Bodies -

Sun - S - 1 Earth - E - 2 Moon - M - 3 Spacecraft - SC - 4

2.1.2 Parameters -

Mass - m
Radius/Distance - r
Center of Mass - CM
Gravitational Constant - G
Gravitational Parameter - mu = G*m

[ ]:
```
# Formatting Strings and Values
prec = 6 # floating point precision
mass = 'kg'
distance = 'km'
accel = 'km/s^2'

# Given Parameters
G = 6.67408E-11 # m^3 * kg^-1 * s^-2, Gravitational Constant

# Given distances (semi-major axes)
r_E_M = 384400 # km
r_E_SC = 1.5e6
r_E_S = 149597898
```

```
# Gravitational Parameters
mu_E = 398600.4415e9 # m^3 * s^-2
mu_M = 4902.8005821478e9
mu_S = 132712440017.99e9

# Masses of Bodies
m2 = mu_E/G # kg
m3 = mu_M/G
m4 = 6500
m1 = mu_S/G

print(f'Earth Mass: {m2:.{prec}e} {mass}',
      f'Moon Mass: {m3:.{prec}e} {mass}',
      f'Spacecraft Mass: {m4:.{prec}e} {mass}',
      f'Sun Mass: {m1:.{prec}e} {mass}', sep='\n')
```

```
Earth Mass: 5.972365e+24 kg
Moon Mass: 7.346032e+22 kg
Spacecraft Mass: 6.500000e+03 kg
Sun Mass: 1.988475e+30 kg
```

[ ]:
```
# Distances from the Sun
r_S_E = r_E_S
r_S_M = r_S_E + r_E_M
r_S_SC = r_S_E + r_E_SC

# Total Mass
m_total = m2 + m3 + m4 + m1 # kg

# CM distance from Sun
r_S_CM = (r_S_E * m2 + r_S_M * m3 + r_S_SC * m4) / m_total

# Distances from CM
r_E = r_S_E - r_S_CM
r_M = r_S_M - r_S_CM
r_SC = r_S_SC - r_S_CM
r_S = 0 - r_S_CM

print(f'Earth Distance from Sun: {r_S_E:.0f} {distance}',
      f'Moon Distance from Sun: {r_S_M:.0f} {distance}',
      f'Spacecraft Distance from Sun: {r_S_SC:.0f} {distance}', sep='\n')
print('\n')
print(f'Sun Distance from CM: {r_S:.{prec}f} {distance}',
      f'Earth Distance from CM: {r_E:.{prec}f} {distance}',
      f'Moon Distance from CM: {r_M:.{prec}f} {distance}',
      f'Spacecraft Distance from CM: {r_SC:.{prec}f} {distance}', sep='\n')
```

```
Earth Distance from Sun: 149597898 km
Moon Distance from Sun: 149982298 km
Spacecraft Distance from Sun: 151097898 km


Sun Distance from CM: -454.855159 km
Earth Distance from CM: 149597443.144841 km
Moon Distance from CM: 149981843.144841 km
Spacecraft Distance from CM: 151097443.144841 km
```

3 Part b)

[ ]:
```
# Calculate acceleration contribution on spacecraft by other bodies
a_sc_s = -G * m1 / ((r_SC - r_S)**2)
a_sc_e = -G * m2 / ((r_SC - r_E)**2)
a_sc_m = -G * m3 / ((r_SC - r_M)**2)
a_sc = a_sc_s + a_sc_e + a_sc_m

print(f'The acceleration contribution from the Sun on the spacecraft is:␣
 ↪{a_sc_s:.{prec}f} {accel}',
      f'The acceleration contribution from the Earth on the spacecraft is:␣
 ↪{a_sc_e:.{prec}f} {accel}',
      f'The acceleration contribution from the Moon on the spacecraft is:␣
 ↪{a_sc_m:.{prec}f} {accel}',
      f'The total acceleration on the spacecraft is: {a_sc:.{prec}f} {accel}',␣
 ↪sep='\n')
```

```
The acceleration contribution from the Sun on the spacecraft is: -5812.925925
km/s^2
The acceleration contribution from the Earth on the spacecraft is: -177.155752
km/s^2
The acceleration contribution from the Moon on the spacecraft is: -3.939374
km/s^2
The total acceleration on the spacecraft is: -5994.021051 km/s^2
```

4 Part c)

[ ]:
```
# Calculate distances between spacecraft and bodies
r41 = r_S - r_SC
r42 = r_E - r_SC
r43 = r_M - r_SC
print('\n')
print(f'The distance between the spacecraft and the Sun is: {abs(r41):.0f}␣
 ↪{distance}',
      f'The distance between the spacecraft and the Earth is: {abs(r42):.0f}␣
 ↪{distance}',
```

```
    f'The distance between the spacecraft and the Moon is: {abs(r43):.0f}␣
↪{distance}', sep='\n')
```

```
The distance between the spacecraft and the Sun is: 151097898 km
The distance between the spacecraft and the Earth is: 1500000 km
The distance between the spacecraft and the Moon is: 1115600 km
```

5 Part e)

```
[ ]: G = 6.67E-20 # redefining gravitational constant for km

# Calculate acceleration terms
accel_24_dom = -G * (m2 + m4) * (-r42)/(abs(-r42)**3)
accel_24_sun_dir = G * m1 * r41/(abs(r41)**3)
accel_24_sun_ind = - G * m1 * -r_S_E/(abs(-r_S_E)**3)
accel_24_moon_dir = G * m3 * r43/(abs(r43)**3)
accel_24_moon_ind = - G * m3 * r_E_M/(abs(r_E_M)**3)
accel_24 = accel_24_dom + accel_24_sun_dir + accel_24_sun_ind +␣
↪accel_24_moon_dir + accel_24_moon_ind

print(
    f'The dominant acceleration (caused by Earth) on the distance between Earth␣
↪and the Spacecraft is: {accel_24_dom:.{prec}e} {accel}',
    f'The direct and indirect perturbation accelerations cause by the Sun on␣
↪the Spacecraft are: {accel_24_sun_dir:.{prec}e} {accel} and␣
↪{accel_24_sun_ind:.{prec}e} {accel} respectively',
    f'The direct and indirect perturbation accelerations cause by the Moon on␣
↪the Spacecraft are: {accel_24_moon_dir:.{prec}e} {accel} and␣
↪{accel_24_moon_ind:.{prec}e} {accel} respectively',
    f'The total acceleration between Earth and the Spacecraft is: {accel_24:.
↪{prec}e} {accel}',
    sep='\n')
```

```
The dominant acceleration (caused by Earth) on the distance between Earth and
the Spacecraft is: -1.770475e-07 km/s^2
The direct and indirect perturbation accelerations cause by the Sun on the
Spacecraft are: -5.809372e-06 km/s^2 and 5.926456e-06 km/s^2 respectively
The direct and indirect perturbation accelerations cause by the Moon on the
Spacecraft are: -3.936966e-09 km/s^2 and -3.315980e-08 km/s^2 respectively
The total acceleration between Earth and the Spacecraft is: -9.706041e-08 km/s^2
1.1708381027261887e-07
```