## PROBLEM SET 9 SOLUTIONS

Physics 2021

1. $\quad \theta=31 \operatorname{arcmin} \quad d=384,000 \mathrm{~km} \quad \tan \theta=\mathrm{D} / \mathrm{d}$

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D=d \tan \theta=(384,000 \mathrm{~km}) \tan (31 / 60)=3463 \mathrm{~km}
$$

2. $\tan \theta=\mathrm{D} / \mathrm{d} \quad \mathrm{d}=384,000 \mathrm{~km} \quad \mathrm{D}=12,756 \mathrm{~km}$
$\tan \theta=(\mathbf{1 2 , 7 5 6} \mathbf{k m}) /(\mathbf{3 8 4}, 000 \mathrm{~km})=\mathbf{0 . 0 3 3 2}$
$\theta=1.9$ degrees $\quad$ (Almost $4 x$ larger than the Full Moon appears to us.)
3. $\mathbf{d}=384,400 \mathrm{~km} \quad R_{\text {earth }}=6378 \mathrm{~km} \quad R_{\text {moon }}=1738 \mathrm{~km}$
$x=\mathbf{d}-R_{\text {earth }}-R_{\text {moon }}=384,400-6378-1738=376,284 \mathrm{~km}$
$\mathbf{v}=\mathbf{c}=3 \times 10^{8} \mathrm{~m} / \mathrm{s}$
$t=x / c=(376,284,000 \mathrm{~m}) /\left(3 \times 10^{8} \mathrm{~m} / \mathrm{s}\right)=1.25 \mathrm{~s}$
4. 

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\mathrm{D}=3476 \mathrm{~km} \quad \mathrm{R}=1738 \mathrm{~km} \quad \mathcal{M}=7.348 \times 10^{22} \mathrm{~kg}
$$

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\begin{aligned}
& \text { Density }=\mathcal{M} / \mathrm{V}=\mathcal{M} /\left[(4 \pi / 3) \mathrm{R}^{3}\right] \\
&=\left(7.348 \times 10^{22} \mathrm{~kg}\right) /\left[(4 \pi / 3)\left(1738 \times 10^{3} \mathrm{~m}\right)^{3}\right] \\
&=\left(7.348 \times 10^{22} \mathbf{~ k g}\right) /\left(2.199 \times 10^{19} \mathrm{~m}\right) \\
&= 3341 \mathrm{~kg} / \mathrm{m}^{3}=3.341 \mathrm{~g} / \mathrm{cm}^{3}
\end{aligned}
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The surface rocks of the Moon and Earth have a density around $3300 \mathrm{~kg} / \mathrm{m}^{\mathbf{3}}$. However, the average density of the Earth is about $5500 \mathrm{~kg} / \mathrm{m}^{3}$. Therefore, there must be a significant amount of material with a density greater than $5500 \mathrm{~kg} / \mathrm{m}^{3}$ in the Earth's interior, whereas there would be far less of such material in the Moon's interior since its average density is not much more than that of its surface rocks.
5. $m=80 \mathrm{~kg}$

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\begin{aligned}
& W=G m \mathcal{M}_{\text {moon }} / R^{2} \\
& =\left(6.67 \times 10^{-11} \mathrm{~N} \mathrm{~m}^{2} / \mathrm{kg}^{2}\right)(80 \mathrm{~kg})\left(7.348 \times 10^{22} \mathrm{~kg}\right) /\left(1738 \times 10^{3} \mathrm{~m}\right)^{2} \\
& =129.8 \mathrm{~N}
\end{aligned}
$$

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\begin{aligned}
& m=80 \mathrm{~kg} \quad \mathcal{M e a r t h}=5.974 \times 10^{24} \mathrm{~kg} \quad \mathrm{R}=6378 \mathrm{~km} \\
& \mathrm{~W}=\mathrm{G} m \mathcal{M e a r t h}^{m} / \mathrm{R}^{2} \\
& =\left(6.67 \times 10^{-11} \mathrm{~N} \mathrm{~m}^{2} / \mathrm{kg}^{2}\right)(80 \mathrm{~kg})\left(5.974 \times 10^{24} \mathrm{~kg}\right) /\left(6378 \times 10^{3} \mathrm{~m}\right)^{2} \\
& =783.6 \mathrm{~N}
\end{aligned}
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6. The "man-made" seismic events were important because (1) naturally occurring moonquakes are rare and (2) the epicenters were at the surface instead of deep inside the Moon.
7. Impact breccias are formed over a series of impact events. Therefore we would not expect to find many younger than 3.1 billion years because impacts have been rare since then. However, a few would have been formed.
8. The average densities tell us that the Moon's core is a smaller fraction of the Moon's size compared to the Earth's core. If the Moon had formed independently at the same time as the Earth, then we would expect the relative sizes of the cores to be the same. The small size of the Moon's core suggests that the Moon formed from material similar to the Earth's crust and mantle after differentiation had occurred. The collisional ejection theory makes this very statement.
