Answer to Essential Question 8.2: We could determine the net force on each object quantitatively, but Figure 8.6 shows that the object experiencing the largest-magnitude net force is the object of mass 3*m* in cases 1 and 2, and the object of mass 2*m* in case 3.

In general, in the case of three objects of different mass arranged in a line the object experiencing the largest net force will be one of the objects at the end of the line, the one with the larger mass. The object in the middle will not have the largest net force because the two forces it experiences are in opposite directions.

8-3 Gravitational Field

Let's discuss the concept of a gravitational field, which is represented by $\vec{g}$. So far, we have referred to $\vec{g}$ as "the acceleration due to gravity", but a more appropriate name is "the strength of the local gravitational field."

A field is something that has a magnitude and direction at all points in space. One way to define the gravitational field at a particular point is in terms of the gravitational force that an object of mass *m* would experience if it were placed at that point:

$$\vec{g} = \frac{\vec{F}_G}{m}.$$ (Equation 8.2: **Gravitational field**)

The units for gravitational field are N/kg, or m/s^2.

A special case is the gravitational field outside an object of mass *M*, such as the Earth, that is produced by that object:

$$\vec{g} = -\frac{GM}{r^2}\hat{r},$$ (Equation 8.3: **Gravitational field from a point mass**)

where *r* is the distance from the center of the object to the point. The magnitude of the field is GM / r^2, while the direction is given by $-\hat{r}$, which means that the field is directed back toward the object producing the field.

One way to think about a gravitational field is the following: it is a measure of how an object, or a set of objects, with mass influences the space around it.

Visualizing the gravitational field

It can be useful to draw a picture that represents the gravitational field near an object, or a set of objects, so we can see at a glance what the field in the region is like. In general there are two ways to do this, by using either field lines or field vectors. The field-line representation is shown in Figure 8.7. If Figure 8.7 (a) represents the field at the surface of the Earth, Figure 8.7 (b) could represent the field at the surface of another planet where *g* is twice as large as it is at the surface of the Earth. In both these cases we have a **uniform field**, because the field lines are equally spaced and parallel. In Figure 8.7 (c) we have zoomed out far from a planet to get a wider perspective on how the planet affects the space around it, while in Figure 8.7 (d) we have done the same thing for a different planet with half the mass, but the same radius, as the planet in (c).

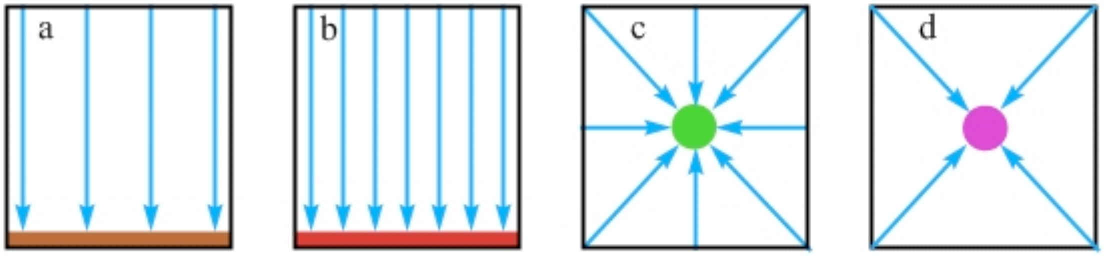

Figure 8.7: Field-line diagrams for various situations. Diagrams *a* and *b* represent uniform gravitational fields, with the field in *b* two times larger than that in *a*. Diagrams *c* and *d* represent non-uniform fields, such as the fields near a planet. The field at the surface of the planet in *c* is two times larger than that at the surface of the planet in *d*.

Question: How is the direction of the gravitational field at a particular point shown on a field-line diagram? What indicates the relative strength of the gravitational field at a particular point on the field-line diagram?

Answer: Each field line has a direction marked on it with an arrow that shows the direction of the gravitational field at all points along the field line. The relative strength of the gravitational field is indicated by the density of the field lines (i.e., by how close the lines are). The more lines there are in a given area the larger the field.

A second method of representing a field is to use field vectors. A field vector diagram has the nice feature of reinforcing the idea that every point in space has a gravitational field associated with it, because a grid made up of equally spaced dots is superimposed on the picture and a vector is attached to each of these grid points. All the vectors are the same length. The situations represented by the field-line patterns in Figure 8.7 are now re-drawn in Figure 8.8 using the field-vector representation.

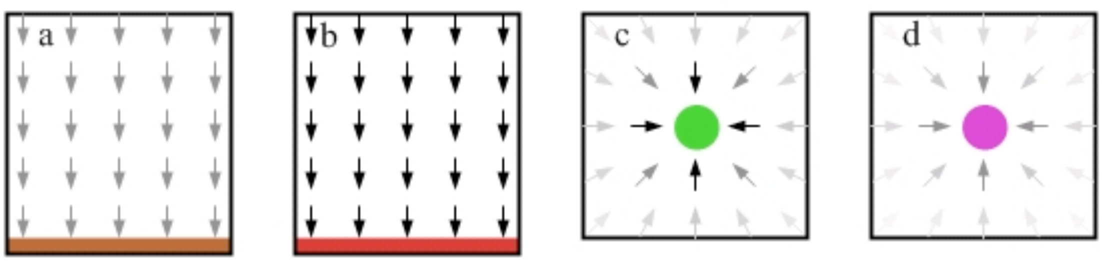

Figure 8.8: Field-vector diagrams for various situations. In figures *a* and *b* the field is uniform and directed down. The field vectors are darker in figure *b,* reflecting the fact that the field has a larger magnitude in figure *b* than in figure *a*. Figures *c* and *d* represent non-uniform fields, such as those found near a planet. Again, the fact that each field vector in figure *c* is darker than its counterpart in figure *d* tells us that the field at any point in figure *c* has a larger magnitude than the field at an equivalent point in figure *d*.

Related End of Chapter Exercises: 18, 36.

Essential Question 8.3: How is the direction of the gravitational field at a particular point shown on a field-vector diagram? What indicates the relative strength of the gravitational field at a particular point on the field-vector diagram?