MAGNETISM
by
LAPWARE

The basic principle of the magnetic compass is that magnetic materials of the same polarity (same poles) repel each other and those of opposite polarity (unlike poles) attract.

The magnetic compass magnets are acted on by the horizontal component of the Earth's total magnetic force. The greatest directive force is exerted on the magnetic compass when the vessel is near the magnetic equator. The vertical angle between the horizontal and the magnetic line of force is the dip. Magnetic dip is a measurement of the angle between the horizontal and the magnetic line of force. The line which connects the points of zero magnetic dips (the points of the earth's surface where there is no dip) is the magnetic equator. The points of the Earth's surface where the magnetic dip is 90° are the magnetic poles.

The advantage of the magnetic compass found aboard vessels is its reliability due to its essential simplicity. As a vessel changes course to starboard, the compass card in a magnetic compass remains aligned with compass north.

The heading of a vessel is indicated by the Lubber's line on the (magnetic) compass. As a vessel changes course to starboard, the compass card in a magnetic compass remains aligned with compass north.

When a magnetic compass is not in use for a prolonged period of time it should be shielded from direct sunlight.

Electrical wiring, an iron pipe or radio would influence a magnetic compass.

The MOST important feature of the material used for making the binnacle of a standard magnetic compass is that it is nonmagnetic.

Induced Magnetism

Magnetism which is present only when the material is under the influence of an external field is called induced magnetism. Induced magnetism is found in soft iron. At the magnetic equator there is no induced magnetism in the vertical soft iron because there is no vertical component of the Earth's magnetic field.

Error may be introduced into a magnetic compass by:

- Making a structural change to the vessel
- A short circuit near the compass
- Belt buckles

The soft iron spheres mounted on arms on the binnacle compensate for induced magnetism in the horizontal soft iron (in a vessel).

Permanent Magnetism

Permanent magnetism is found in hard iron and is caused by the earth's magnetic field affecting the ship's hard iron during construction. The permanent magnetism of a vessel may change in polarity due to steaming from the north magnetic hemisphere to the south magnetic hemisphere.

The permanent magnetism of a vessel may change in strength due to all of the following:

- Major structural repairs
- Being moored on a constant heading for a long period of time
- A collision with another vessel
- Being struck by lightning – this might also change polarity of a vessel.

Magnets are placed in horizontal trays in the compass binnacle to compensate for the permanent magnetism of the vessel.

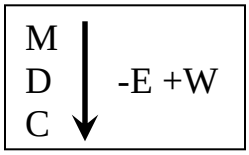
Deviation

Magnetic compass deviation is the angular difference between magnetic north and compass north. The (angle) difference between magnetic heading (magnetic meridian) and compass heading (axis of the compass card) is deviation. Deviation is the horizontal angle between the magnetic meridian and the north-south line of the magnetic compass.

Deviation in a compass is caused by the influence of the magnetic materials of the vessel or the vessel's magnetism. The compass deviation changes as the vessel changes heading. The total magnetic effects which cause deviation of vessel's compass can be broken down into a series of components referred to as coefficients.

If a ship is proceeding towards the magnetic equator, the uncorrected deviation due to permanent magnetism decreases. If the compass heading and the magnetic heading are the same then there is no deviation on that heading.

If the magnetic heading is **greater** than the compass heading, the north end of the compass heading is deflected to the **right** or **clockwise**, the deviation is **EAST.**



If the magnetic heading is **less** than the compass heading, the north end of the compass heading is deflected to the **left** or **counterclockwise**, the deviation is WEST.

Magnets in the binnacles of magnetic compasses are used to reduce the effect of deviation. A single vertical magnet placed underneath the compass in the binnacle is used to compensate for deviation caused by the vessel's inclination (heel) from the vertical.

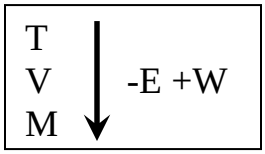
The purpose of the soft iron spheres mounted on arms on the binnacle is to compensate for induced magnetism in the horizontal soft iron (of a vessel) and are used to remove deviation which is maximum on intercardinal (NE, SE, SW, NW) compass headings.

Variation

Magnetic variation changes with a change in the vessel's position. Variation is not constant; it is different with every change in geographical location of your vessel. Variation in a compass is caused by magnetism from the earth's magnetic field. Variation is the angular measurement between the magnetic meridian and the geographic meridian. To find a magnetic course from a true course you must apply variation. In other words, Variation is the difference in degrees between true north and magnetic north. True heading differs from magnetic heading by variation. Variation is a compass error that you cannot correct.

On an isomagnetic chart, the line of zero variation is the **agonic line**, the line which connects the points (of the earth's surface) of zero magnetic dip. In other words, there is NO Variation on this line.

The compass rose on a nautical chart indicates both variation and an annual rate of variation change.



The chart indicates the variation was 3° 45' E in 1988, and the annual change is increasing 6'. If you use the chart in 1991 the variation you should apply is 4° 03' E.

3º 45' E
+ 18' (6' x 3 yrs)
4º 03' E

The chart indicates the variation was 3° 45' W in 1988, and the annual change is increasing 6'. If you use the chart in 1991 the variation you should apply is 4° 03' W.

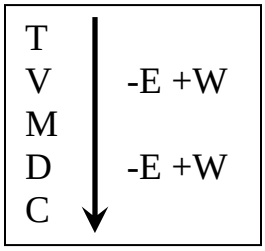
3º 45' W
+ 18' (6' x 3 yrs)
4º 03' W

The chart indicates the variation was 3° 45' W in 1988, and the annual change is decreasing 6'. If you use the chart in 1991 the variation you should apply is 3° 27' W.

3º 45' W
- 18' (6' x 3 yrs)
3º 27' W

Compass Error

The standard magnetic compass heading differs from the true heading by compass error. Likewise, the compass heading of a vessel differs from the true heading by compass error. Compass error is equal to the combined variation and deviation. In other words, when changing from a compass course to a true course you should apply BOTH variation and deviation.



If a magnetic compass is NOT affected by any magnetic field other than the Earth's, compass error and variation are equal.

The compass error of a magnetic compass that has no deviation is equal to variation.

To find a magnetic compass course from a true course you must apply deviation and variation.

Compass Adjustment

The principle purpose of magnetic compass adjustment is to reduce the deviation as much as possible. Before a magnetic compass is adjusted you should ensure that the Flinders bar and quadrantal spheres are free of permanent magnetism and should be so **tested annually**. When adjusting a compass for error, a deviation table should be made after **adjusting the fore-and-aft and athwartships permanent magnets**.

Magnets are placed in horizontal trays in the compass binnacle to compensate for the permanent magnetism of the vessel. When adjusting a magnetic compass using the fore-and-aft permanent magnets, you should use the magnets in pairs, from the bottom up, with the trays at the lowest point of travel.

To center a compass bowl in its binnacle, you should have the ship on an even keel, heading north or south, and adjust the screws until **no change of heading by the compass is observed if you raise and lower the heeling magnet**. When crossing the magnetic equator the heeling magnet should be inverted.

To expedite the at sea adjustment of the magnetic compass the following dock side adjustments should be made in the following order:

1) The **Flinders bar or fore-and-aft magnets** are magnetic compass corrector(s) that:
    a. can be used for the permanent magnetism of the vessel AND
    b. can be used for induced magnetism in vertical soft iron, or
    c. can be used for error caused by the vertical component of the Earth's magnetic field which results in induced magnetism in vertical soft iron which changes with latitude, or
    d. can be used for the coefficient of deviation,
    e. can be set while the vessel is on a heading of magnetic **east** or magnetic **west**, and
    f. **CANNOT** be set while the vessel is on a heading of magnetic north or magnetic south.

    When adjusting a magnetic compass using the **Fore-and-Aft permanent magnets**, you should use the magnets in pairs, from the bottom up, with the trays at the lowest point of travel.

2) The **quadrantal spheres** are magnetic compass corrector(s) that:
    a. can be used to remove deviation on the intercardinal headings,
    b. can be set while the vessel is on a heading of magnetic **northeast** or magnetic **southeast**.

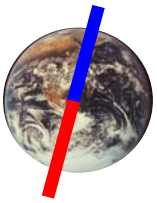
3) The **heeling or athwartships magnets** are magnetic compass corrector(s) that:
    a. can be set while the vessel is on a heading of magnetic **north** or magnetic **south.**
    b. **CANNOT** be set on a heading of magnetic east or magnetic west.

4) After compass adjustments are made, steady the vessel on a compass point. If deviation exists, **ONLY <u>one-half the error</u>** is corrected **<u>towards</u>** the compass point.

The only magnetic compass corrections that correct for both permanent and induced effects of magnetism are the heeling magnets and consequently must be readjusted with radical changes in latitude.

Heeling error is defined as the change of the deviation for a heel of 1° while the vessel is on a compass heading of 000°.

The Earth's north magnetic pole is colored **blue**.
The Earth's south magnetic pole is colored **red**.



The north pole of a magnet is painted **red**.
The north seeking ends of compass magnets are colored **red**.

The south pole of a magnet is **blue**.
The south seeking ends of a compass magnet are colored **blue**.

When a vessel changes course from one cardinal heading (N, S, E, W) to another cardinal heading while adjusting the compass, after the new heading is reached, the vessel should steam on that course **for at least two minutes** before the adjustment is made.

You have completed the magnetic compass adjustments on magnetic east and magnetic south. The vessel is now steady on magnetic **north** but the compass reads 004°.

- Adjust the **athwartship heeling magnets**
- Until the compass reads 002°

You have completed the magnetic compass adjustments on magnetic east and magnetic south. The vessel is now steady on magnetic **north** but the compass reads 356°.

- Adjust the **athwartship heeling magnets**
- Until the compass reads 358°

You have completed the magnetic compass adjustments on magnetic east and magnetic south. The vessel is now steady on magnetic **west** but the compass reads 266°.

- Adjust the compass with the **Flinders bar or fore-and-aft magnets**
- Until the compass reads 268°

You have completed the magnetic compass adjustments on magnetic east and magnetic south. The vessel is now steady on magnetic **west** but the compass reads 276°.

- Adjust the compass with the **Flinders bar or fore-and-aft magnets**
- Until the compass reads 273°

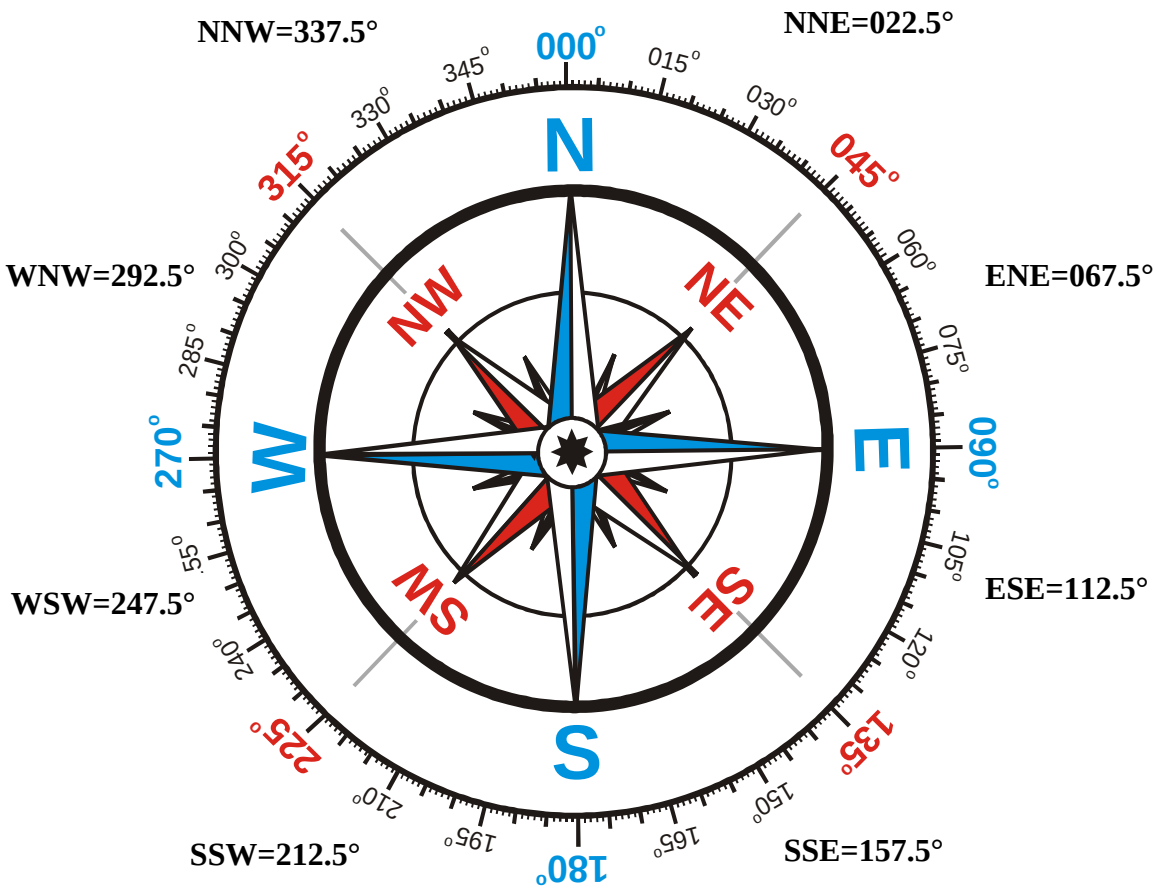
One point of a compass is equal to 11.25°

Eight points of a compass are equal to 90°

There are 32 points in a compass card.

A magnetic compass card is marked in 360°.

Cardinal Points **Intercardinal Points**



Before a magnetic compass is adjusted the **Flinders Bar and quadrantal spheres** must be checked (**ANNUALLY)** to ensure that they are free of permanent magnetism.

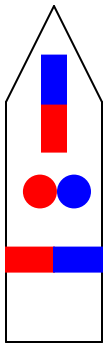
When adjusting a magnetic compass using the **fore-and-aft permanent magnets**, you should use the magnets in pairs, from the bottom up, with the trays at the lowest point of travel.

When adjusting a compass for error, a deviation table should be made after **adjusting the fore-and-aft and athwartships permanent magnets**.

To center a compass bowl in its binnacle, you should have the ship on an even keel, heading north or south, and adjust the screws until **no change of heading by compass is observed if you raise or lower the heeling magnet**.

After compass adjustments are made, steady the vessel on a compass point. If deviation exists, **ONLY <u>one-half the error</u>** is corrected **<u>towards</u>** the compass point.

TVMDC East is least West is best when uncorrecting (going from True to Compass is uncorrectiong)



Fore-Aft Tray (Flinders Bar) Magnets for E/W Heading

Spheres for Intercardinal Heading

Athwartships (Heeling) Magnets for N/S Heading

A vessel is heading magnetic **east** and its magnetic compass indicates a heading of 086°. To remove this error during compass adjustment:

- if the **red ends** of the magnets are aft you should lower the **fore-and-aft tray**.
- if the **blue ends** of the magnets are aft, and the fore-and-aft tray is at the top, you should add some magnets.

A vessel is heading magnetic **east** and its magnetic compass indicates a heading of 093°. To remove this error during compass adjustment:

- if the **blue ends** of the magnets are forward you should raise the **fore-and-aft tray**.
- f the **red ends** of the magnets are aft you should raise the fore-and-aft tray.
- if the **red ends** of the magnets are forward, and the fore-and-aft tray is at the bottom, you should remove some magnets.

A vessel is heading magnetic **northwest** and its magnetic compass indicates a heading of 312°. To remove this error during compass adjustment:

- if the **quadrantal spheres** are all the way out, replace them with smaller spheres.
- if the quadrantal spheres are all of the way in, move the spheres out.
- if the quadrantal spheres are arranged athwartships, if the quadrantal spheres are all of the way out, replace them with smaller spheres.

A vessel is heading magnetic **northwest** and its magnetic compass indicates a heading of 317°. To remove this error during compass adjustment:

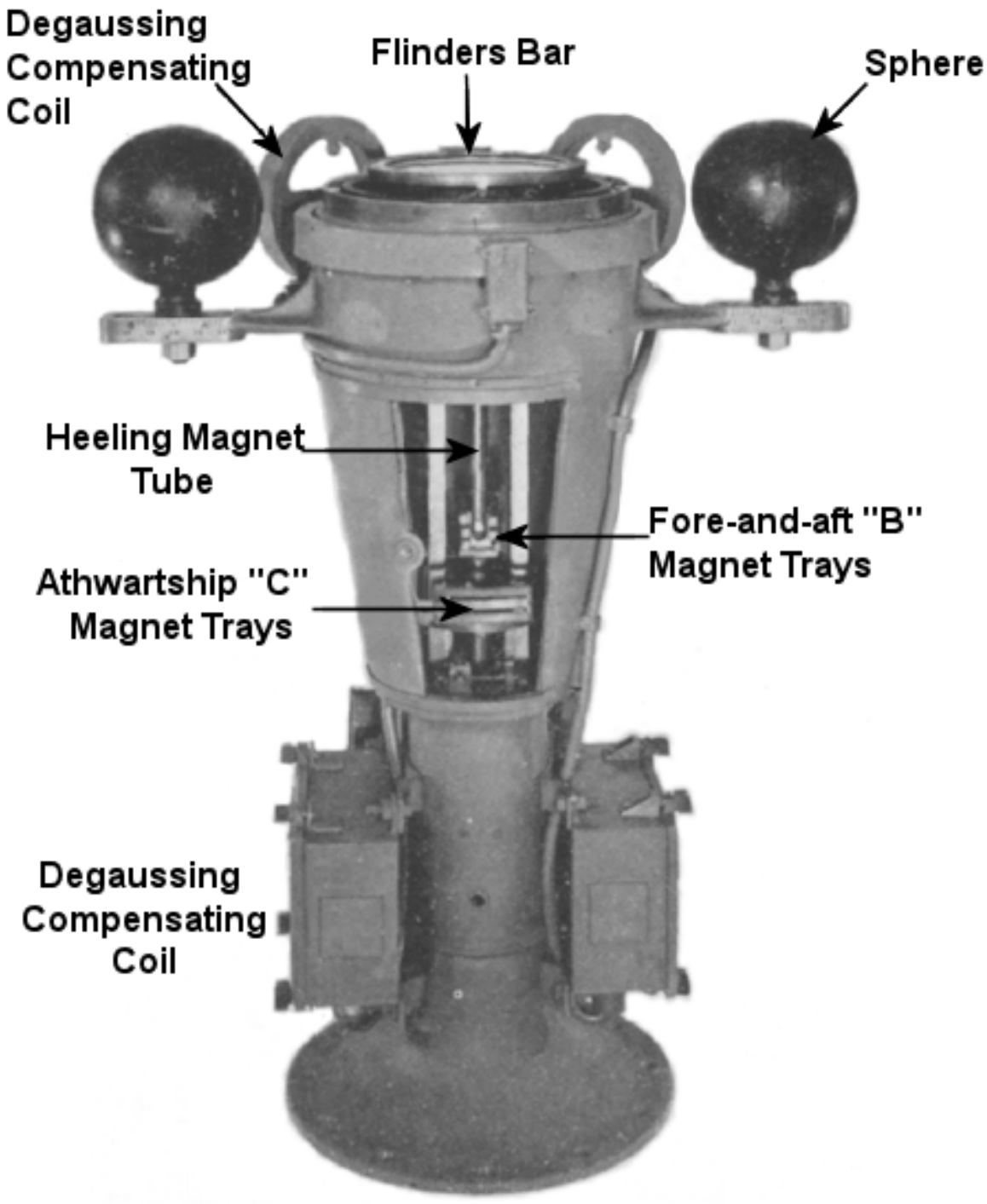
- you should move the **quadrantal spheres** in.
- if the quadrantal spheres are in as far as possible, replace them with larger spheres.
- if the quadrantal spheres are out as far as possible, move the quadrantal spheres in.

A vessel is heading magnetic **north** and its magnetic compass indicates a heading of 003°. To remove this error during compass adjustment:

- if the **red ends** are to starboard the **athwartships magnets** should be lowered.
- if the **red ends** are to starboard, and the athwartships tray is at the bottom, you should remove some magnets.
- if the **red ends** are to port and the tray is at the bottom, you should raise the tray.
- if the **red ends** are to port the athwartships magnets should be raised.
- If the **blue ends** of the magnets are to port and the athwartships tray is at the bottom you should reverse the magnets.
- Raise or lower the athwartship magnets

A vessel is heading magnetic **north** and its magnetic compass indicates a heading of 356°. To remove this error during compass adjustment:

- if the **red ends** of the magnets are to port you should lower the **athwartships magnets** tray.
- if the **red ends** of the magnets are to starboard, and the athwartships tray is at the top, you should add some more magnets.
- if the **blue ends** of the magnets are to starboard, and the athwartships tray is at the bottom, you should remove some magnets.



Binnacle with compass and correctors

D052NG

Fore-and-aft and athwartship magnets			Quadrantal spheres			Flinders bar		
Deviation → Magnets ↓	Easterly on east ***and*** westerly on west. (+B error)	Westerly on east ***and*** easterly on west. (-B error)	Deviation → Spheres ↓	E on NE, W on SE, E on SW, ***and*** W on NW (+D error)	W on NE, E on SE, W on SW, ***and*** E on NW (-D error)	Deviation change with latitude change → Bar ↓	E on E ***and*** W on W when sailing toward equator from north latitude or away from equator to south latitude.	W on E ***and*** E on W when sailing toward equator from north latitude or away from equator to south latitude.
No fore and aft magnets in binnacle.	Place magnets **red forward**.	Place magnets **red aft**.	No spheres on binnacle.	Place **spheres athwartship**.	Place **spheres fore and aft**.	No bar in holder.	Place required amount of bar **forward**.	Place required amount of bar **aft**.
Fore and aft magnets red forward.	Raise magnets.	Lower magnets.	Spheres at athwartship position.	Move spheres toward compass or use larger spheres.	Move spheres outwards or remove.	Bar forward of binnacle.	Increase amount of bar forward.	Decrease amount of bar forward.
Fore and aft magnets red aft.	Lower magnets.	Raise magnets.	Spheres at fore and aft position.	Move spheres outward or remove.	Move spheres toward compass or use larger spheres.	Bar aft of binnacle.	Decrease amount of bar aft.	Increase amount of bar aft.
Deviation → Magnets ↓	Easterly on north ***and*** westerly on south. (+C error)	Westerly on north ***and*** easterly on south. (-C error)	Deviation → Spheres ↓	E on N, W on E, E on S, ***and*** W on W (+E error)	W on N, E on E, W on S, ***and*** E on W (-E error)	↑ Bar Deviation change with latitude change →	W on E ***and*** E on W when sailing toward equator from south latitude or away from equator to north latitude.	E on E ***and*** W on W when sailing toward equator from south latitude or away from equator to north latitude.
No athwartship magnets in binnacle.	Place **athwartship magnets red starboard**.	Place **athwartship magnets red port**.	No spheres on binnacle.	Place spheres at port forward and starboard aft intercardinal points.	Place spheres at starboard forward and port aft intercardinal positions.	**Heeling magnet** (Adjust with changes in magnetic latitude)		
Athwartship magnets red starboard.	Raise magnets.	Lower magnets.	Spheres at athwartship position.	Slew spheres clockwise through required angle.	Slew spheres counter-clockwise through required angle.	If compass north is attracted to high side of ship when rolling, ***raise*** the heeling magnet if red end is up and ***lower*** the heeling magnet if blue end is up.		
Athwartship magnets red port.	Lower magnets.	Raise magnets.	Spheres at fore and aft position.	Slew spheres counter-clockwise through required angle.	Slew spheres clockwise through required angle.	If compass north is attracted to low side of ship when rolling, ***lower*** the heeling magnet if red end is up and ***raise*** the heeling magnet if blue end is up. **NOTE:** Any change in placement of the heeling magnet will affect the deviation on all headings.		

Magnetism – Question Summary

17 Theory of Magnetism
773, 783, 793, 813, 823, 833, 843, 953, 2152, 2158, 2159, 2164, 2252, 2292, 2332, 2412, 2452

1 Compass Error
903

33 Magnetic Compass Error
853, 863, 873, 883, 893, 913, 923, 933, 1203, 1213, 1223, 1243, 1363, 1382, 1461, 1514, 1542, 1633, 1811, 1830, 1840, 1850, 1860, 1870, 1872, 1880, 1890, 2000, 2010, 2020, 2030, 2040, 2191

11 Use Of Magnetic Compass
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9 Magnetic Compass Variation
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10 Magnetic Compass Deviation
599, 754, 1193, 1233, 1253, 1263, 1273, 1283, 1293, 1303

1 Miscellaneous Publications
1033

39 Magnetic Compass Adjustment
963, 993, 1003, 1013, 1023, 1043, 1053, 1063, 1083, 1093, 1103, 1113, 1123, 1133, 1153, 1163, 1173, 1183, 1759, 1832, 2016, 2018, 2098, 2168, 2174, 2178, 2184, **2209**, 2214, 2222, 2224, 2234, **2282**, 2290, 2369, **2402**, **2442**, 2482, 2542

23 Compass Adjustment
1792, 2179, 2185, 2188, 2189, 2195, 2217, 2221, 2223, 2225, 2227, 2229, 2232, 2242, 2245, 2249, 2257, 2276, 2315, 2322, 2354, 2362, 2395

1) 22 General
1003, 1043, 1053, 1063, 1083, 1093, 1103, 1113, 1123, 1133, 1153, 1163, 1173, 1183, 2168, 2174, 2178, 2184, 2214, 2222, 2224, 2290, 2482

2) 9 Fore-Aft and Flinders Bar Magnets
East and West Heading
1792, 2016, 2018, 2098, 2223, 2276, 2315, 2354, 2395

3) 9 Spheres (Quadrantal)
Intercardinal Points – NE SE SW NW
1013, 1023, 1033, 1832, 2179, 2217, 2221, 2245, 2257

4) 14 Athwartship or Heeling Magnets
North and South Heading
963, 993, 1759, 2188, 2189, 2195, 2225, 2229, 2232, 2234, 2242, 2249, 2369, 2542

5) 8 Adjustment for Deviation one-half of error towards compass point
Magnetic West
2185, **2209**, 2227, **2282**
Magnetic North
2322, 2362, **2402**, **2442**

144 TOTAL COUNT

NOTE
ALL Magnetic Compass Adjustment and Compass Adjustment questions shown above reference diagram d052ng (page 10) EXCEPT questions 2209, 2282, 2402 and 2442.

